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ENVIRONMENTAL AND MOTION DATA OBTAINED DURING THE RO/RO DISCHARGE FACILITY TRIAL CONDUCTED WITH THE SS ATLANTIC BEAR

by

Grant A. Rossignol

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December 1983 DTNSRDC/SPD-515-05

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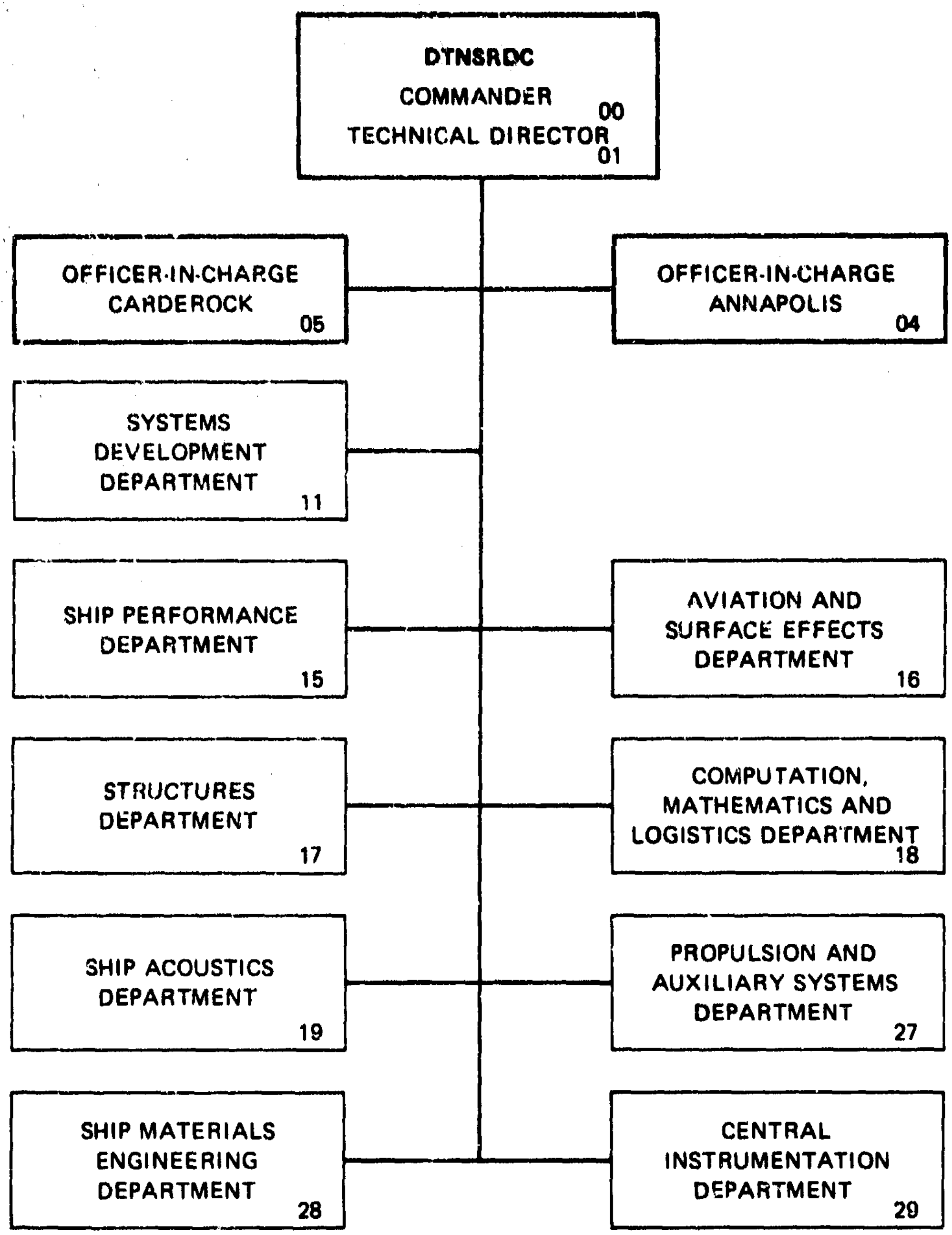

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This report presents environmental and motion data obtained during the RO/RO Discharge Facility Trial conducted with the SS ATLANTIC BEAR, a non self-sustaining RO/RO ship. Interface operations were conducted between the ship and the beach using a portable ramp, a Causeway Platform, and a variety of lighterage in moving assorted vehicles.

The operating environment, from 16 to 20 September 1983 in the Chesapeake Bay off Fort Story, included fair skies and mild temperatures (70 to 91° F).

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The sea conditions were fairly severe at the beginning of the trial, but became quite calm. The significant wave heights ranged from nearly 4 feet (1.2 meters) to less than 1 foot (0.3 meters). The initial rough seas and associated wave periods of 7 seconds caused large relative motions between the ship and the Causeway Platform. These relative motions created considerable difficulty in the commencement of trial operations.

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NOTATION

B	Maximum beam at the design waterline
LOA	Length overall
$S_{\zeta}(\omega)$	Wave height spectral density ordinate
T	Draft
T_o	Modal wave period
Δ	Displacement (weight)
$(\zeta_w)_{1/3}$	Significant wave height
ω	Angular frequency of the waves

ABSTRACT

This report presents environmental and motion data obtained during the JLOTS II RO/RO Phase Trial conducted with the SS ATLANTIC BEAR, a non self-sustaining RO/RO ship. Interface operations were conducted between the ship and the beach using a portable ramp, Causeway Platform, and a variety of lighterage in moving assorted vehicles.

The operating environment, from 16 to 20 September 1983 in the Chesapeake Bay off Fort Story, included fair skies and mild temperatures (70 to 91°F). The sea conditions were fairly severe at the beginning of the trial, but became quite calm. The significant wave heights ranged from nearly 4 feet (1.2 meters) to less than 1 foot (0.3 meters). The initial rough seas with associated wave energy around a period of 7 seconds caused large relative motions between the ship and Causeway Platform. These relative motions created considerable difficulty in the commencement of trial operations.

ADMINISTRATIVE INFORMATION

The developmental trial conducted with the SS ATLANTIC BEAR and the RO/RO Discharge Facility is an integral part of the Naval Facilities Engineering Command (NAVFAC) program to develop methods for offloading military cargo from merchant ships. The NAVFAC program is CNO Project No. 299, Container Offloading and Transfer System (COTS). The program developmental test designation is DT-IIF-1. The program manager for the subject test is NAVFAC 032B. Technical program development and test direction were provided by the David W. Taylor Naval Ship Research and Development Center (DTNSRDC), Mobile Support Systems Office, Code 1190, Task Area Y0816.002 and Work Unit 1190-158.

INTRODUCTION

Future major amphibious operations conducted by the Department of Defense (DoD) will, in many cases, rely extensively on United States flag commercial shipping. The Roll-On/Roll-Off (RO/RO) ship seems to be particularly well suited to enable rapid deployment of military rolling stock (such as tanks, trucks, and artillery) in support of any major DoD operation. These operations usually take place over undeveloped beaches, however; while RO/RO ships require complete pierside facilities for offloading and backloading. To help solve this problem, the Navy has developed a RO/RO Discharge Facility for the movement of rolling stock between commercial RO/RO ships and military lighterage. The Navy developmental work was done under the Container-Over-the-Shore (COTS) Program. The RO/RO Discharge Facility consists of the Causeway Platform,

lighterage, and auxiliary equipment. Ship fenders and a portable ramp were developed to be used during Causeway Platform interface operations with non self-sustaining RO/RO ships.

Joint Logistics Over-the-Shore (JLOTS) II is a program sponsored by the Director, Defense Test and Evaluation to evaluate the joint services' capabilities to provide sustained throughput of containerized, breakbulk, and bulk petroleum cargo across an austere beach. The program is designed to determine the services' ability to discharge large commercial ships offshore with equipment that has been developed by the Army, Navy, and Marine Corps to meet this difficult and demanding mission. To help satisfy the objectives of JLOTS II, a series of trials were planned for 1983 and 1984. These trials consist of three phases: RO/RO, Deployment, and Throughput. The RO/RO phase planning consisted of trials with two commercial RO/RO ships: one equipped with a ramp (self-sustaining) and one not so equipped (non self-sustaining). The RO/RO phase trials were conducted in July (self-sustaining)*[1] and September (non self-sustaining) of 1983.

The RO/RO Discharge Facility trial (non self-sustaining ship) was conducted with the SS ATLANTIC BEAR (a commercial RO/RO ship), in conjunction with the JLOTS II Program. The trial took place from 16 to 20 September 1983 in the Chesapeake Bay off the beach of Fort Story (Virginia Beach, Virginia). The trial operations area is shown in Figure 1. The trial began by mooring the Causeway Platform to the starboard quarter of the ship at the aftermost loading port. The ship end of the ramp was then raised to the loading port and secured. The Causeway Platform was left in place for the duration of the trial. Approximately 70 vehicles were moved from a staging area on the beach to the ship. The evaluation was repeated daily for the remainder of the trial using combinations of LCU and causeway ferry (CWF) lighterage. Figures 2 and 3 show the ATLANTIC BEAR to Causeway Platform interface configuration.

The DTNSRDC Ship Performance Department (Code 1561) was tasked by the DTNSRDC Systems Development Department (Code 1190) to define the prevailing environmental conditions and measure the motions of the ship and Causeway Platform during the trial. Near the end of each day during the trial, a summary of that day's environmental conditions and predictions of the next

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*A complete listing of references is given on page 12.

day's weather (including tides) were reported to the COTS Trial Director. The results of all environmental conditions and motions obtained during the trial are presented in this report.

OBJECTIVES

The primary objectives of the DTNSRDC (Code 1561) effort during the trial were to:

a. Define the prevailing environmental conditions during each day of the trial;

b. Measure the motions of the ship and Causeway Platform;

c. Provide daily summaries of the environmental conditions;

d. Provide daily weather predictions.

DESCRIPTION OF PARTICULARS

The principal characteristics of the ATLANTIC BEAR, a 1610 Series LCU (both Army and Navy), a warping tug, and a typical causeway section are given in Table 1. The ATLANTIC BEAR is a GREAT LAND Class merchant RO/RO ship under contract to the Military Sealift Command (MSC). The ship has a length overall of 790 feet (241 meters), a beam of 105 feet (32 meters), a draft of 28 feet (9 meters), and a corresponding displacement of 16,100 tons (16,357 tonnes). The ship is not equipped with a vehicle ramp (non self-sustaining); but does have a stern loading port and three loading ports on the starboard side for use with an independent ramp.

The RO/RO Discharge Facility consists of the Causeway Platform, lighterage, and auxiliary equipment. The Causeway Platform is made up of six Navy causeway sections linked together by flexor side and end connectors to form a platform three sections wide and two long. The overall platform is 65 feet (19.7 meters) wide and 180 feet (54.4 meters) long. Causeway ferries (strings of four causeway sections end connected only) and 1610 series LCU's represent the lighterage used in moving the vehicles between the Causeway Platform and the beach. The causeway ferries (CWF's) link directly to the end of the Causeway Platform opposite the ship, but the LCU marriages require that a causeway B section (with a rhino horn in place) be first linked to the Causeway Platform end opposite the ship. A report covering 1982 trials conducted with the Causeway Platform describes the physical characteristics of the lighterage, miscellaneous vessels, causeway sections, and miscellaneous hardware in more

detail**. Figures 4 and 5 show photographs of the ATLANTIC BEAR, a warping tug, a causeway B section, a CWF, and a 1610 series LCU.

INSTRUMENTATION

The DTNSRDC Portable Data Collection Center (PORDACC) trailer was used as a central site for monitoring, collecting, and processing the data during the trial. PORDACC was installed on the Army LCU 1583 (CHATTANOOGA) along with a leased (30 KW, three-phase diesel) generator. The CHATTANOOGA was tied along the port side of the ATLANTIC BEAR for the duration of the trial. Figures 6 and 7 show the CHATTANOOGA alongside the ATLANTIC BEAR and details of the arrangements of PORDACC and the generator on the deck, respectively. Figure 8 shows the interior of PORDACC.

Measurements were made of environmental conditions, ship motions, platform motions, and ramp acceleration. The environmental conditions measured were: wave height, wind speed, wind direction, current speed, precipitation, water temperature, air temperature, and barometric pressure. In addition, estimates were made of: wave direction, current direction, visibility, and tide extreme times. Figure 9 shows photographs of the wave buoy and the mooring line arrangement used during the trial. Figures 10 and 11 show a sketch and photograph, respectively, of the wave buoy as actually deployed. The location of the buoy is shown in Figure 1, which was in approximately 40 feet (12.1 meters) of water. The buoy is a wave rider displacement buoy which has double integrating circuitry. Vertical wave acceleration is converted to wave height, prior to transmitting the signal back to PORDACC. To prevent ship blockage of the wave buoy signal, the receiving antenna was located high on the ship's superstructure, as shown in Figure 12.

The wind speed and direction were measured by a wind meter installed on the ship's superstructure (Figure 12). The current speed was measured by a current meter hung over the stern of the CHATTANOOGA. The current direction changed only from ebb to flood and thus was not necessary to measure. Figure 13 shows a photograph of the current meter and digital indicator. Supplementary current

**Rossignol, G.A., "MS CYGNUS, SS AMERICAN TROJAN, and Causeway Platform Facility Relative Motion Evaluation," Report DTNSRDC/SPD-515-03 (Feb 1983). (This report has a restricted distribution and is not available to the general public.)

speed estimates and predicted tide extreme times were obtained from the standard NOAA National Ocean Survey tidal current and tide tables. Figure 14 shows photographs of the rain gage and temperature probes which were used to monitor precipitation, water temperature, and air temperature. The rain gage and air temperature probe were installed on the roof of PORDACC, while the water temperature probe was hung over the portside of the CHATTANOOGA. Barometric pressure was monitored using a barometer in PORDACC. Visibility was estimated periodically each day using a combination of the CHATTANOOGA's radar, nautical charts, and observations of known land references.

Ship, platform, and ramp motions were measured during the trial. Measurements were made of pitch, roll, and vertical acceleration of both the ship and the Causeway Platform using custom designed motion measurement packages. These packages consist of a weather tight box housing a pitch/roll gyroscope and vertical accelerometer. The ship package was installed on the outboard edge of the main deck (port side) near amidships. The platform package was installed on the platform near the end of the ramp (out of the way of vehicle traffic) with the pitch motion being along the length of the platform (perpendicular to the centerline of the ship). Ramp acceleration was measured by an accelerometer installed horizontally at the top of the ramp so that the transverse acceleration towards and away from the ship could be measured. Figure 15 shows photographs of the motion measurement package. The heading of the ship was measured by virtue of a hookup to the CHATTANOOGA gyrocompass. The CHATTANOOGA pitch and roll was also measured by a gyroscope in PORDACC. Table 2 summarizes the measurements, types of transducers, and locations.

MEASUREMENTS AND DATA REDUCTION

Time histories of the following signals were recorded in analog form on strip charts and analog tapes and in digital form on disks:

a. ship pitch;
b. ship roll;
c. ship vertical acceleration;
d. platform pitch;
e. platform roll;
f. platform vertical acceleration;
g. ramp acceleration;
h. ship heading;

i. LCU pitch;

j. LCU roll;

k. wave height;

l. wind speed;

m. wind direction.

The following variables were tabulated from a variety of monitoring devices:

a. water temperature;

b. air temperature;

C. precipitation;

d. visibility;

e. times of tide extremes;

f. current speed;

g. current direction;

h. wave direction;

i. barometric pressure.

A PDP 1123 computer system installed in PORDACC was used to collect and reduce data during the trial. The computer system consists of a central processor, analog-to-digital converter, CRT display, keyboard, dual floppy disk drive, and a printer. Figure 16 shows the computer system components as installed in PORDACC. The signals were sampled at a rate of 5 samples per second using one hertz filter. Fifteen minutes of data were collected every hour during the trial operations, including one night unattended using an automatic collection mode. Real-time data reduction was accomplished during the trial to provide time history statistics, thus enabling daily reports to be made to the COTS Trial Director. The wave height time histories were spectrum analyzed, using a FFT program at DTNSRDC after the trial, to obtain wave spectra. A description of the equations used in the data reduction for the trial data is given in the appendix.

TRIAL CONDITIONS AND PROCEDURE

The trial operations (OPS) area ranged from the ATLANTIC BEAR anchorage in the Chesapeake Bay to the beach at Fort Story (Virginia Beach, Virginia). The ship was anchored (Figure 1) one nautical mile (1.8 kilometers) from the beach

in approximately 40 feet (12.1 meters) of water at a latitude of 36° 56.6' North and a longitude of 76° 03.2' West. The initial phase of the trial involved he installation of the Causeway Platform and portable ramp to the starboard quarter loading port of the ship. Sea conditions [significant wave height between 4 to 5 feet (1.2 to 1.5 meters)] on 14 and 15 September 1983 caused cancellations of attempts to move the Causeway Platform out to the ship. Even on 16 September, the significant wave height was between 2.5 and 4 feet (0.8 to 1.2 meters) during the morning hours. The attempt at mooring the platform to the ship resulted in damage to the platform fender assemblies. Repairs were made at the Amphibious Construction Battalion Two unit at the Little Creek Naval Amphibious Base that afternoon and evening. The following day (17 September), the Causeway Platform was successfully moored; and the ramp was raised into place and secured to the ship until the last day of the trial (20 September). Each day until the end of the trial (17 to 20 September), LCU and CWF lighterage moved vehicles in a round trip between the ship and a staging area on the beach. On 20 September, the ramp was lowered and the platform was removed. The ramp and platform were then reinstalled for a few hours before being permanently removed.

The weather and sea conditions varied considerably during the trial. A storm moving through the area caused trial OPS to be cancelled initially (14 and 15 September) and attempted unsuccessfully on 16 September. The significant wave height ranged from 5 feet (1.5 meters) on 14 September down to 2.5 feet (0.8 meters) by the afternoon of 16 September. On 17 and 18 September, the significant wave height varied from 1.4 to 2.0 feet (0.4 to 0.6 meters). The remaining two days of the trial, the waves were mostly less than one foot (0.3 meters). The winds ranged from light and variable (speed less than 6 knots) to around 10 knots (9 to 13 knots) out of the west. During the actual trial OPS, the weather was nearly ideal, with clear skies and temperatures between 70 and 91° F. The current speed and direction were a function of the tide changes, with a maximum current speed of 1.3 knots (ebb). Table 3 summarizes the environmental conditions which prevailed during the trial.

The wave buoy was deployed on the first day of the trial (16 September). The buoy was moored to an anchor using about 280 feet (84 meters) of anchor line and wire rope. The buoy was located approximately 460 yards (414 meters) northwest of the ship in 40 feet (12.1 meters) of water.

PRESENTATION OF RESULTS

Figure 17 through 21 present wave spectra for each day of the trial. These spectra represent the maximum wave conditions encountered during each day of the trial, with the exception of the first day (16 September). Measurements of wave height did not begin until 1300 hours, but by then the waves had diminished somewhat from the morning hours. The significant wave height during the morning hours was observed to be as large as 4 feet (1.2 meters). The seas were primarily wind generated the first two days of the trial (16 and 17 September) with a modal wave period of about 7 seconds. The last three days (18 through 20 September), the waves became more short and choppy. The modal wave period was around 3.3 seconds with occasional 8 to 9 second swells.

Figure 22 shows the variations in the heading of the ATLANTIC BEAR as the ship (and Causeway Platform) swung about the anchor. The environmental conditions which caused the ship to swing around are also presented in Figure 22. The primary reason for the ship swinging is the changing tides. The ship would typically head West at the time of a maximum low tide (ebb) and swing around to head East at the time of the maximum high tide (flood). Approximately 4 hours after the high or low tide, the ship would then begin to swing. The 180 degree swing would usually take 2 to 3 hours. These heading variations were consistently periodic during the entire trial with the only uncertainty being the direction that the ship would swing. Most of the time the ship would swing with the bow heading passing through North, but a couple of times the bow passed through a South heading. Future RO/RO ship to Causeway Platform interface OPS should make use of the tide change to ship heading relationship. During these future OPS, the times of stationary ship headings should be fairly predictable for wind speeds less than 15 knots.

Figures 22 and 23 present graphical summaries of all environmental data obtained during the trial. The wind data show that the wind direction was out of the West to Southwest for wind speeds around 10 knots and above; but that the wind direction was quite variable for wind speeds of around 5 knots and less. The waves were predominantly out of the North and West. The significant wave height was mostly 1 to 2 feet (0.3 to 0.6 meters) the first three days of the trial; and mostly less than 1 foot (0.3 meters) the last two days of the trial. Although the air temperature ranged between 70° F and 91 °F during the trial, the bay temperature stayed fairly constant around 71° F. Table 3 also summarizes the environmental data.

Tables 4 and 5 and Figure 24 present the motion data obtained during the trial. Tables 4 and 5 summarize significant amplitudes and range values of the ship, Causeway Platform, ramp, and Army LCU (CHATTANOOGA) motions. The range values represent limiting values for the maximum double amplitudes. With the exception of 0800 hours on 18 September, the ship pitch and roll motions were quite small during the trial. During the part of the trial when both ship and platform motions were measured, the platform motions were consistently larger than the ship motions. Since the platform is smaller than the ship, this result is not surprising. The most interesting result is that the maximum ship motions did not always occur during the same time as the maximum platform motions. Since the ship and platform have different resonant natural frequencies, they will respond to different wave periods. The relative motions between the ship and platform will be more significant (to vehicle movement) than the absolute motions of either the ship or the platform. Future developmental trials should use only relative motions as a means of monitoring the effects of motion dynamics on interface OPS. Figure 24 presents graphical summaries of the platform significant pitch, roll, and vertical acceleration. Since the platform was moored to the starboard quarter of the ship and the largest waves were predominantly out of the North, the platform was in the lee of the ship when the ship heading was to the East. When the tidal current caused the ship to head west, the waves approached the end of the platform opposite the ship. The resulting pitch motion was about the same as the roll only because the length of the platform is three times the width. As the wave direction began to shift to out of the Northwest and then to the west, the roll motion increased and the pitch decreased.

The most significant motions which occurred during the trial were during the first day (16 September). Since the Causeway Platform and ramp were in the process of being installed in place alongside the ship, the platform motions could not be measured. The relative motions (ship/ramp and ramp/platform) were severe enough to part lines, cause platform fender damage, and cause a postponement of operations.[2] Transferring personnel and equipment from the Army LCU 1583 (CHATTANOOGA) to the ATLANTIC BEAR by small boat was also quite difficult and hazardous. These relative motions greatly slowed data collection efforts during this day of the trial.

Future ship to lighterage discharge OPS should use only relative motions as criteria for limiting vehicle or cargo movement. Absolute ship, Causeway

Platform, or lighterage motions alone will not represent a true picture of the effects of motions on interface OPS. Since the ship, platform, and lighterage respond to different periods of waves; the sea conditions could cause fairly large amplitudes of relative motions, while the absolute motions are not very large. Relative motions are best obtained from the absolute motions** in the time domain (by calculating new relative motion time histories) due to the complex phase relationships of the motions.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the measurements and observations made during the trial, the following conclusions are drawn concerning the environmental conditions and motions:

a. The sea conditions varied from those associated with a diminishing storm front at the beginning of the trial to fairly calm seas. The significant wave height ranged from about 4 feet (1.2 meters) with a 7 second modal wave period the first day of the trial, to less than 1 foot (0.3 meters) with about a 3 second modal period by the end of the trial.

b. The winds ranged from 1 to 5 knots and variable to 10 to 13 knots out of the West and Southwest.

c. The weather was nearly ideal, with clear skies and temperatures between 70° and 91° F.

d. The ship swung periodically about the anchor point due to the tidal currents associated with tide changes. The ship was initially at a constant East/West heading. Approximately 4 hours after the high/low tide, the ship began to swing and continued for 2 to 3 hours to a 180 degree change of heading.

e. The most significant motions during the trial were not possible to measure due to installation operations of the ramp and Causeway Platform to the ship. The relative motions between the ship, ramp, and platform were severe enough to part lines and cause platform fender damage.

The following recommendations are made regarding future developmental trials or involving vehicle/container ship-to-shore interface operations:

a. Ship/lighterage, ship/platform, and platform/lighterage relative motions should be measured and used as limiting criteria for future interface operations.

b. Advance trial planning should allow the installation of all instrumentation before the commencement of operations so that any problems arising (particularly during the initial stages) during interface operations can be correlated with measured motions and environmental conditions.

REFERENCES

1. Rossignol, Grant A., "Environmental and Motion Data Obtained during the JLOTS II RO/RO Phase Trial Conducted with the MS CYGNUS," Report DTNSRDC/SPD-515-04 (Sept 1983).

2. Vaughters, Theodore G., "Roll-On/Roll-Off (RO/RO) Discharge Facility Tests with MV CYGNUS and SS ATLANTIC BEAR (COTS CNO PROJECT 299, DT-IIF-1," Report DTNSRDC/SDD-83/8 (Nov 1983).

APPENDIX

FORMULAS AND EQUATIONS

I. Time history analysis.

The mean value, $\bar{y}_i$, and the root mean square value, $(RMS)_i$, for a particular measurement are calculated by

$$\bar{y}_i = \frac{1}{N}\sum_{j=1}^{N} y_j$$

and

$$(RMS)_i = \left[\frac{1}{N}\sum_{j=1}^{N} y_j^2\right]^{1/2},$$

where y_j is the instantaneous value of the particular time history, y(t), and N is the number of samples digitized. The standard deviation, σ_i, for a particular measurement is calculated by

$$\sigma_i = \left[(RMS)_i^2 - \bar{y}_i^2\right]^{1/2}.$$

The significant amplitude, $(\tilde{i}_A)_{1/3}$, for a particular measurement is calculated from the standard deviation by

$$(\tilde{i}_A)_{1/3} = 2\sigma_i.$$

For a given time history segment of a particular measurement, y(t), the minimum and maximum values are $y_{j\max}$ and $y_{j\min}$. These values are used to calculate the range R_i, by

$$R_i = |y_{j\max} - y_{j\min}|.$$

Since the largest double amplitude cannot be greater than the range, the range is used to represent a limiting value for the maximum double amplitude.

II. Spectral analysis.

The Fast Fourier Transform (FFT) method was used to obtain spectra for the wave height signals. The wave height spectral ordinate is represented by

$$S_\zeta(\omega), \text{ in feet}^2 \cdot \text{sec (meter}^2 \cdot \text{sec)},$$

where ω is the angular wave frequency in radians per second. By taking the area under the spectrum, A, significant wave height was calculated by

$$(\tilde{\zeta}_w)_{1/3} = 2\sqrt{2}\sqrt{A}.$$

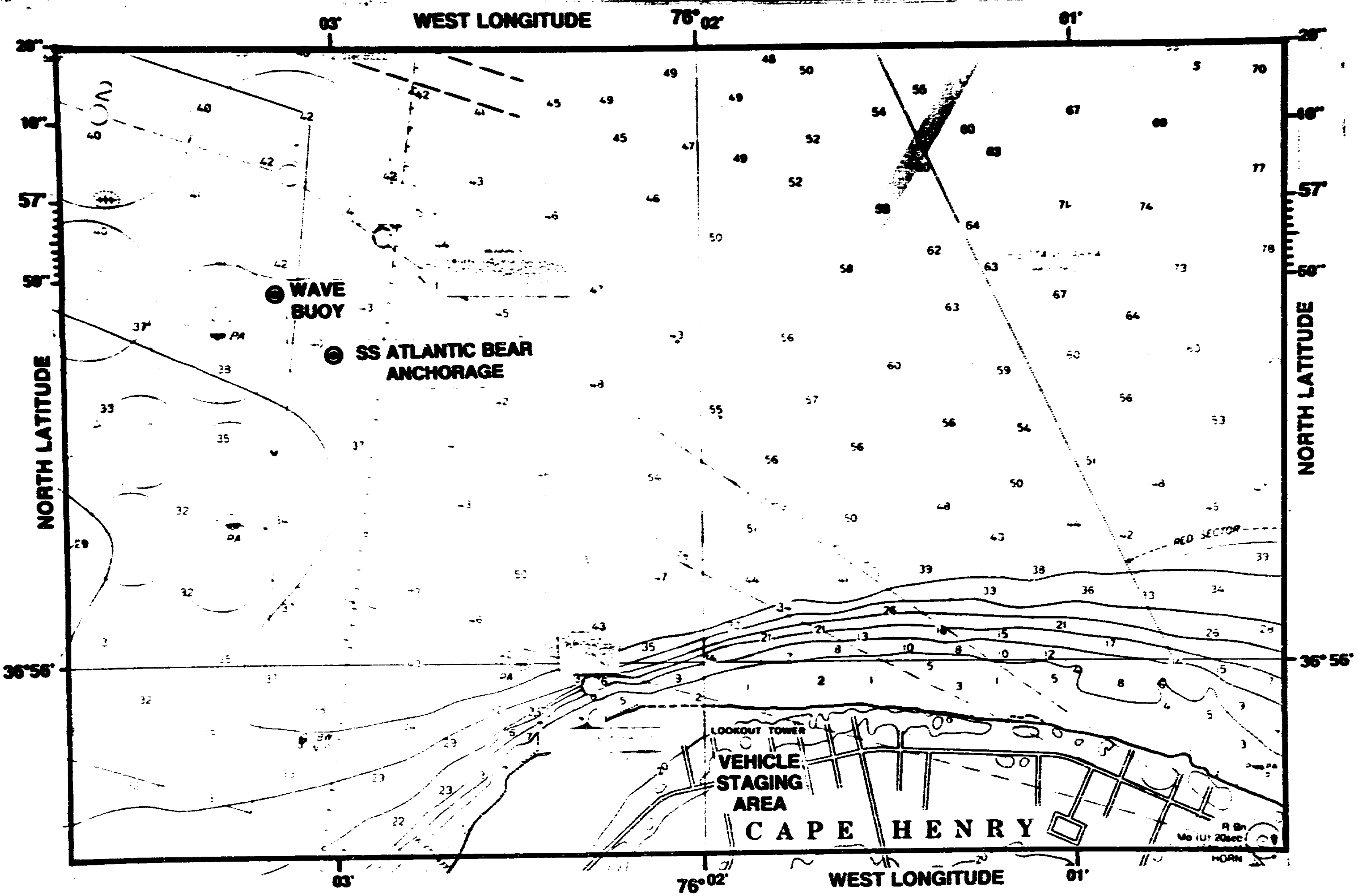

Figure 1 - Nautical Chart of the Trial Operations Area Located in the Chesapeake Bay off the Coast of Virginia Beach (Fort Story)

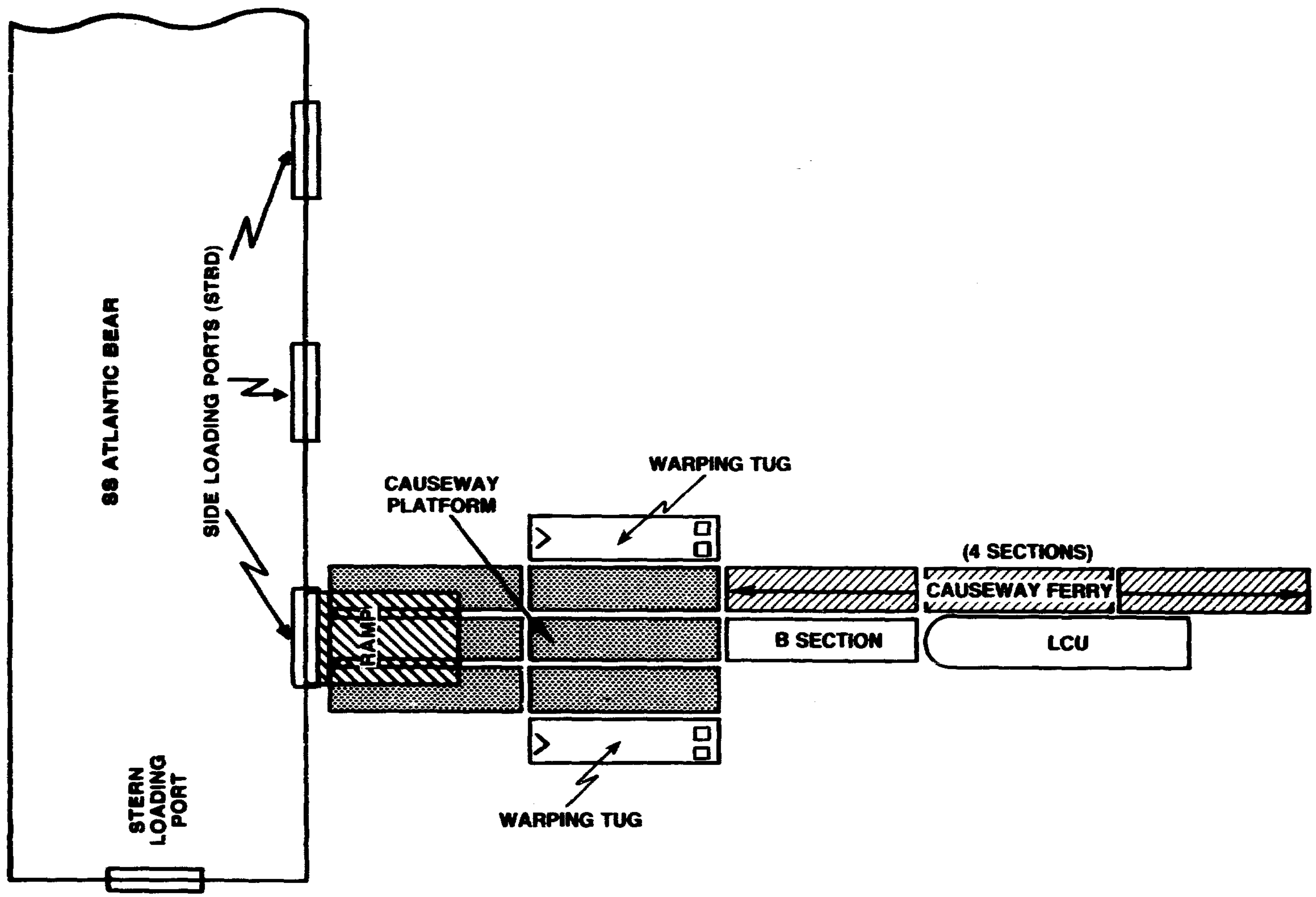

Figure 2 - Sketch of Configuration used during SS ATLANTIC BEAR Interface Showing Relative Positions of Causeway Platform, Ship, Ramp, Warping Tugs, Causeway B Section, Causeway Ferry, and LCU

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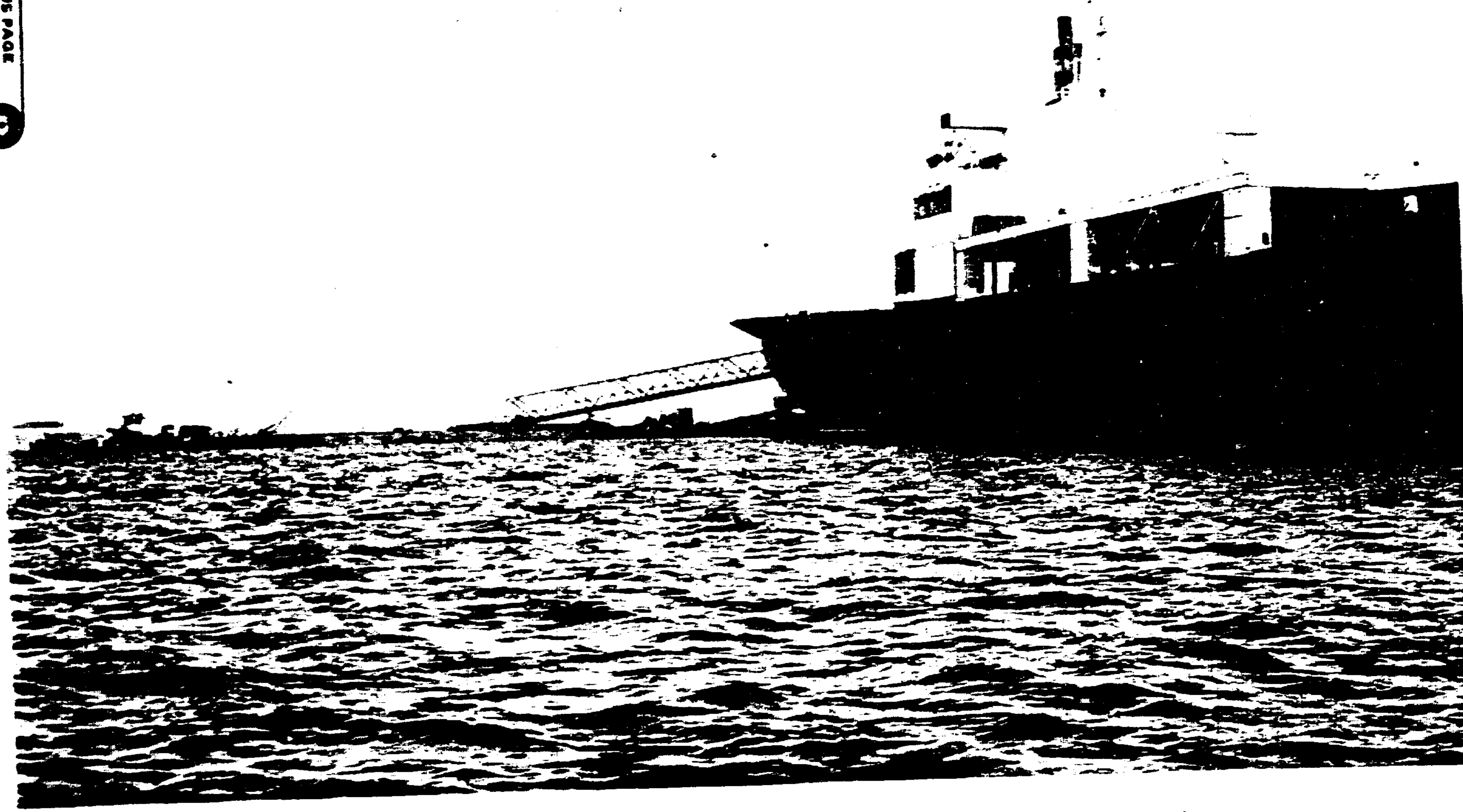


Figure 3 - Photograph of the Causeway Platform in Position at the Starboard Side of the SS ATLANTIC BEAR

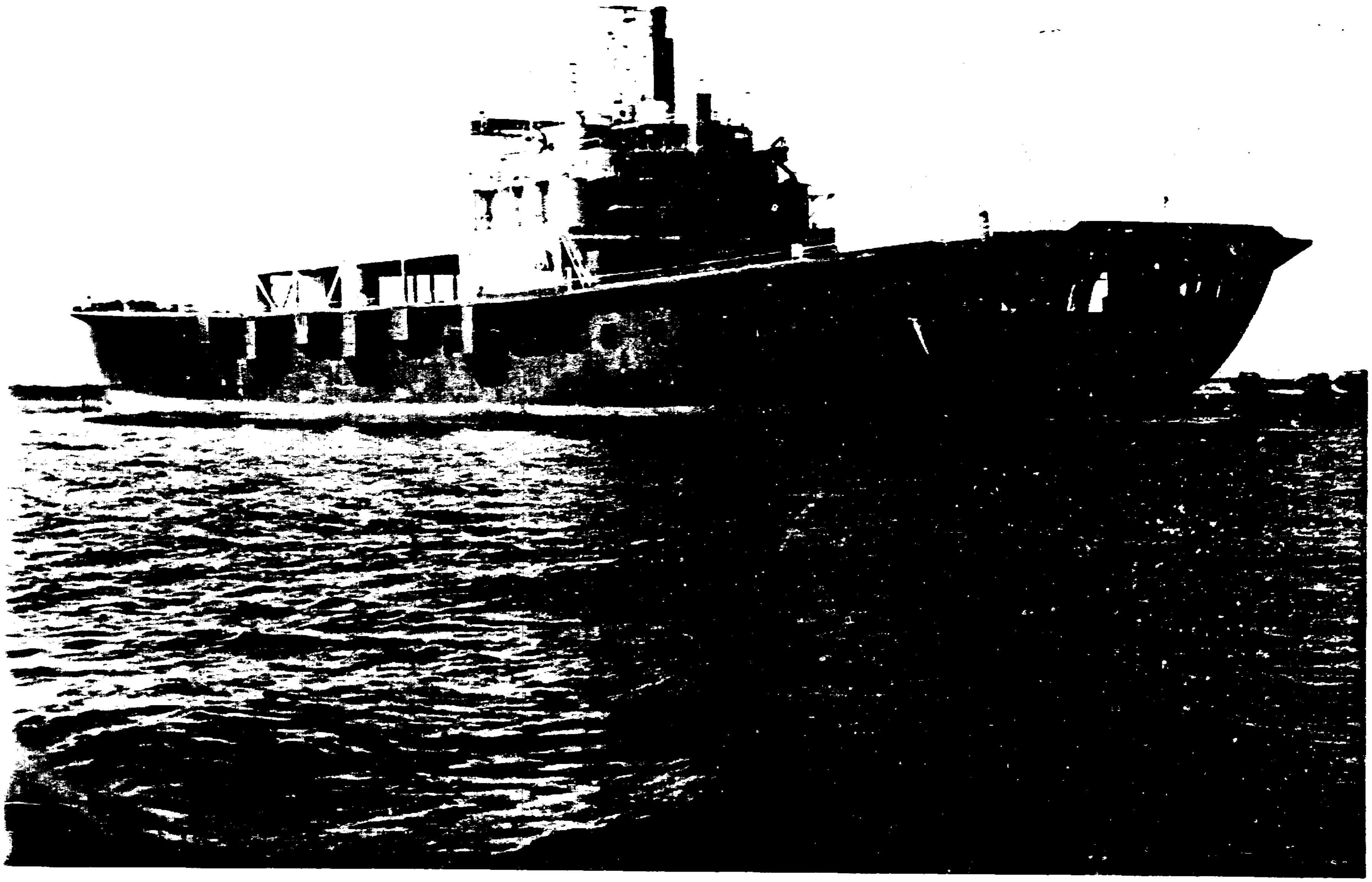
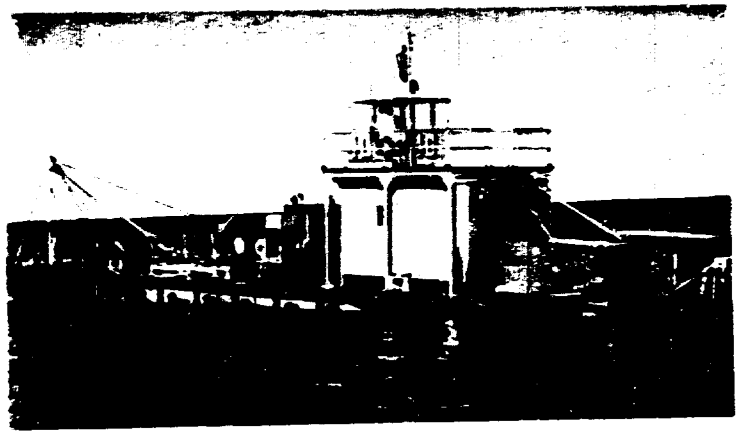
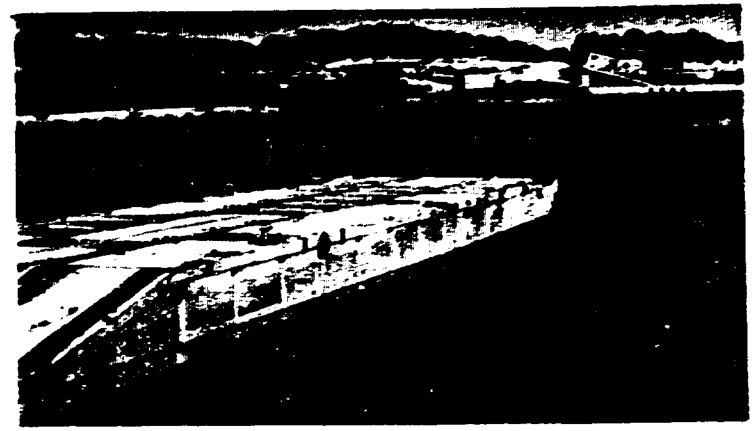


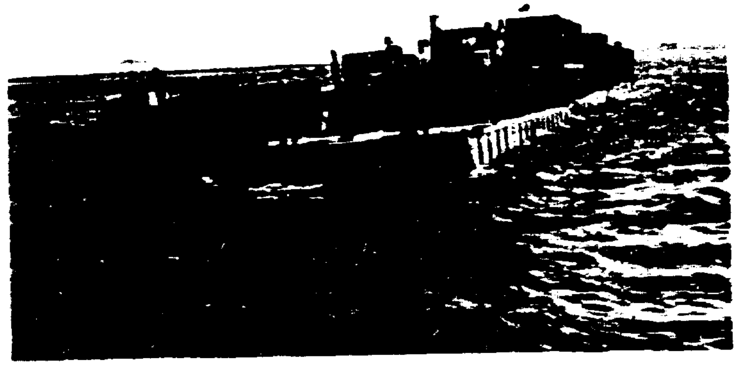
Figure [illegible]. Photograph of the SS ATLANTIC BEAR



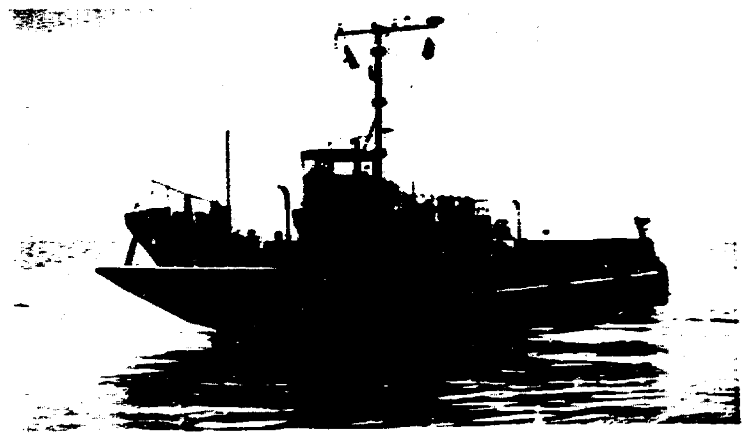
WARPING TUG (WT)
HOME PORT TYPE



CAUSEWAY SECTION (B)



CAUSEWAY FERRY (CWF)



LCU (1610 SERIES)

Figure 5 - Photographs of a Warping Tug (WT), Causeway Section (B), Causeway Ferry (CWF), and LCU (1610 Series)

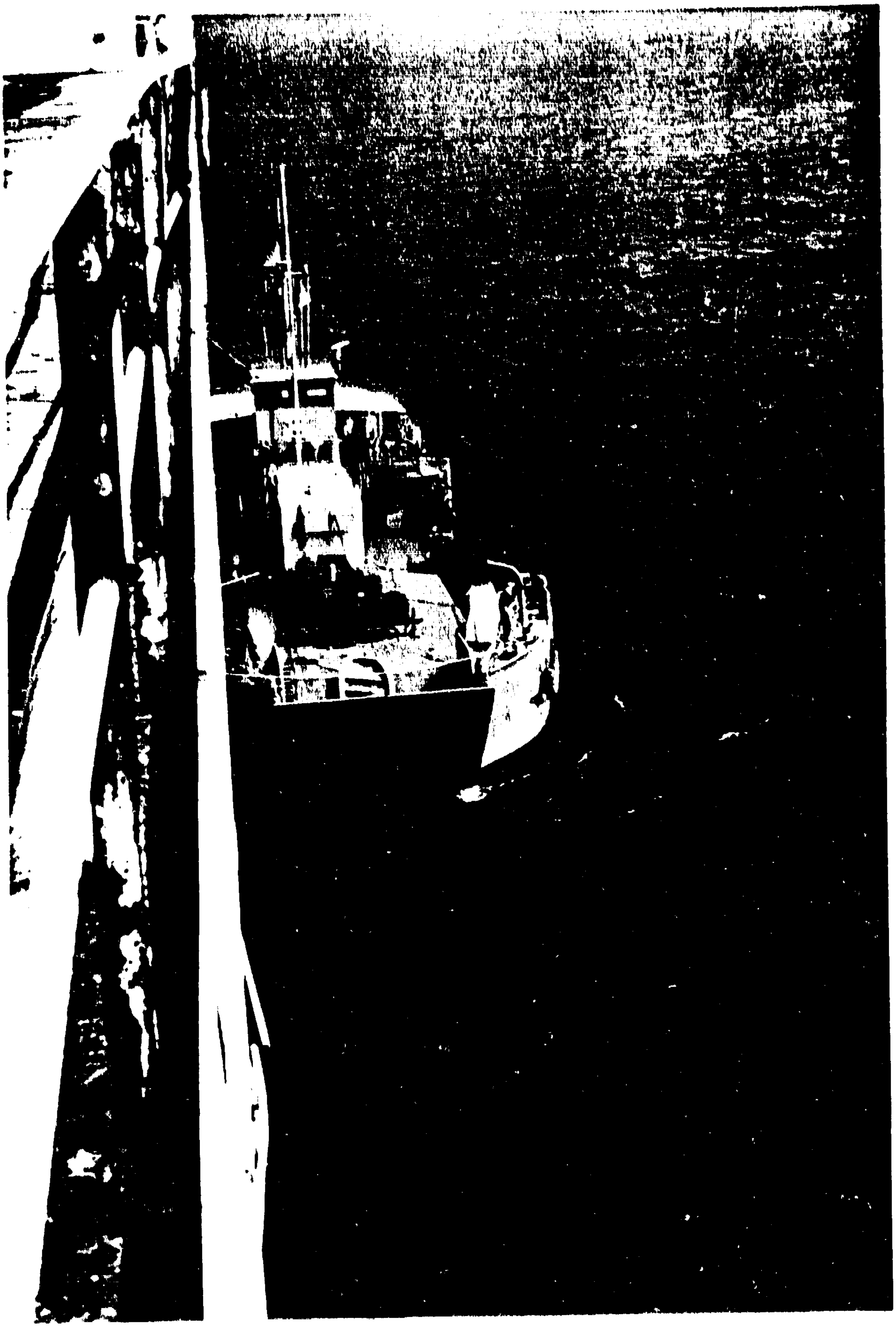


Figure 6 - Photograph of the ARMY LCU 1583 (CHATTANOOGA) [illegible] the SS ATLANTIC BEAR with the Portable Data Collection Center (PORDACC) Trailer on Board

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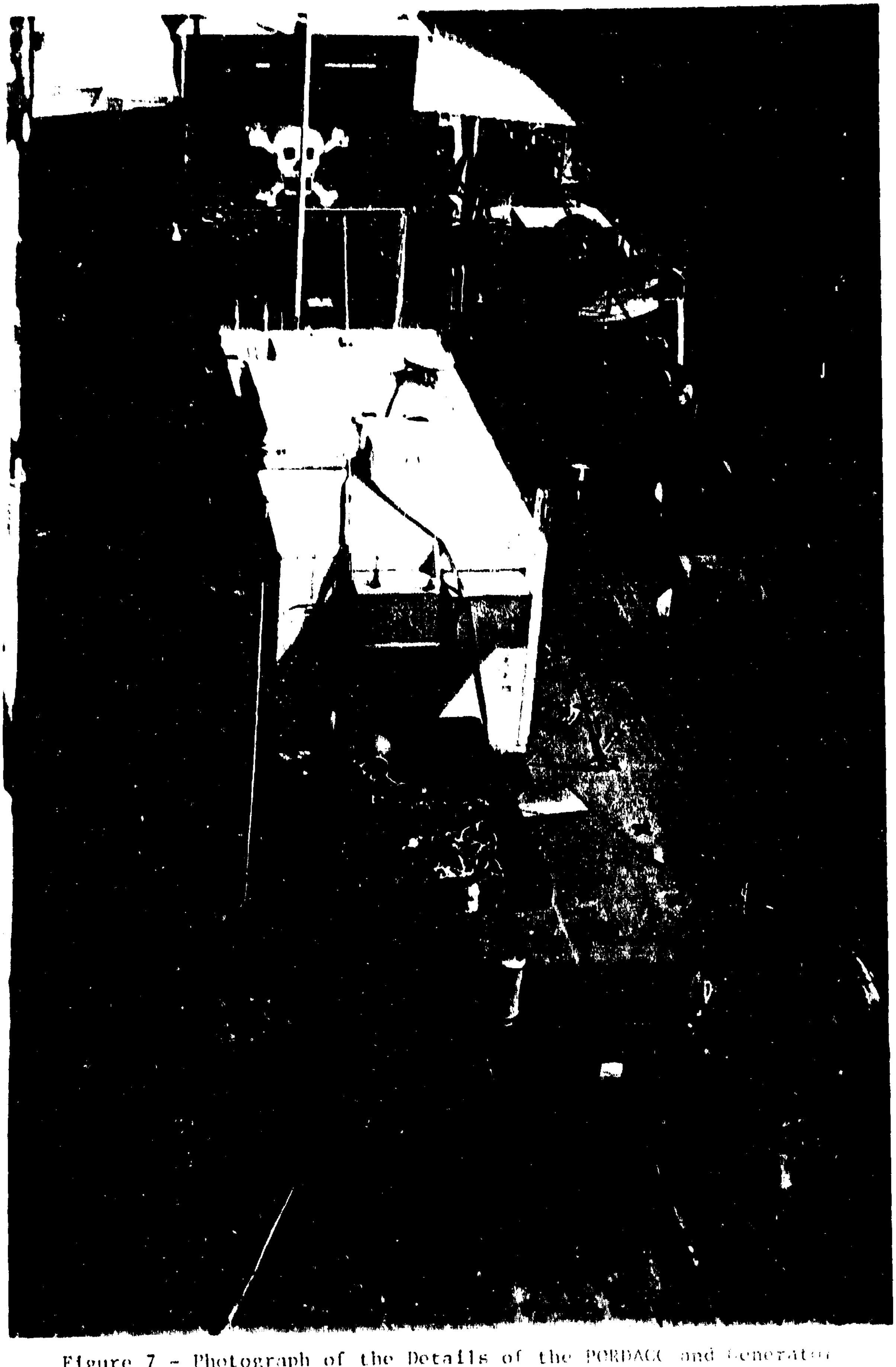
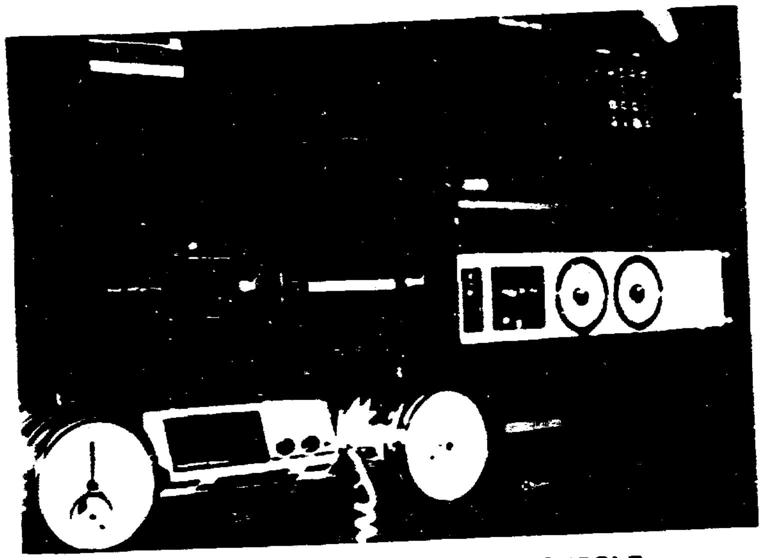
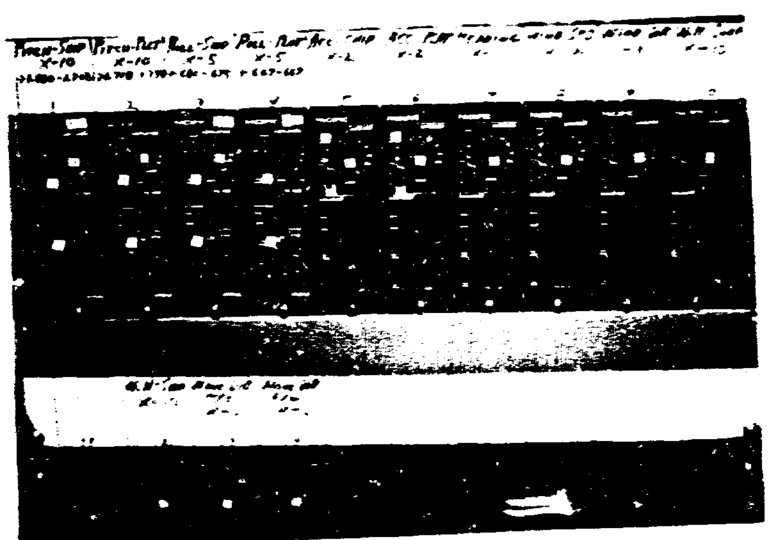


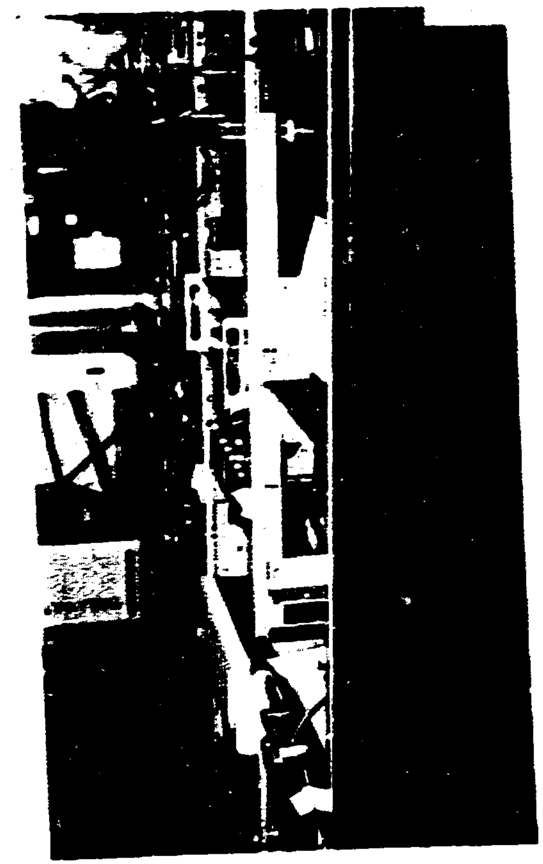
Figure 7 - Photograph of the Details of the PORDACC and Generator Installation on the Army LCU 1583 (CHATTANOOGA)



MONITOR/COMMUNICATIONS CONSOLE

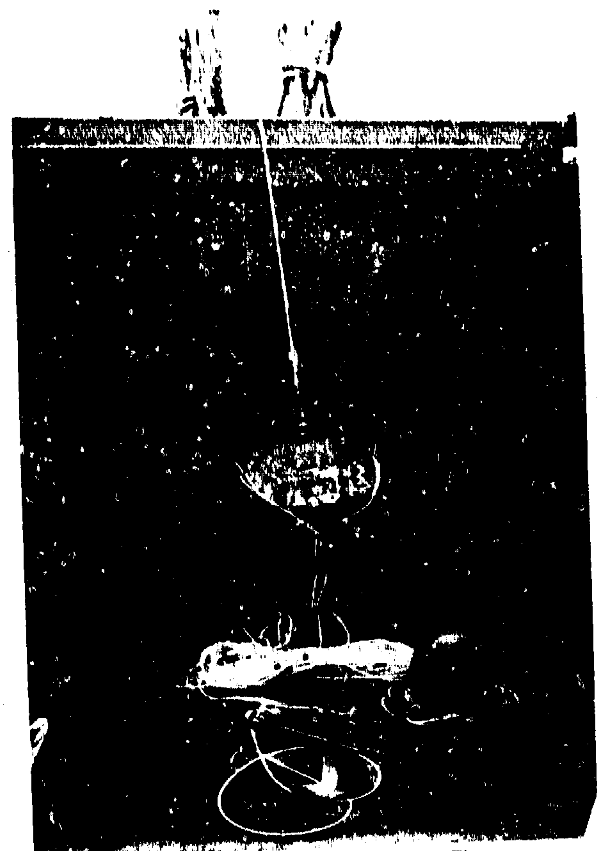


AMPLIFIERS



INSTRUMENTATION RACKS

Figure 8 - Interior Photographs of PORDACC Showing Some of the Equipment/Instrumentation used during the Trial



WAVERIDER BUOY (SURF)

Figure 9 - Photograph of the Wave Buoy and Mooring Line Arrangement

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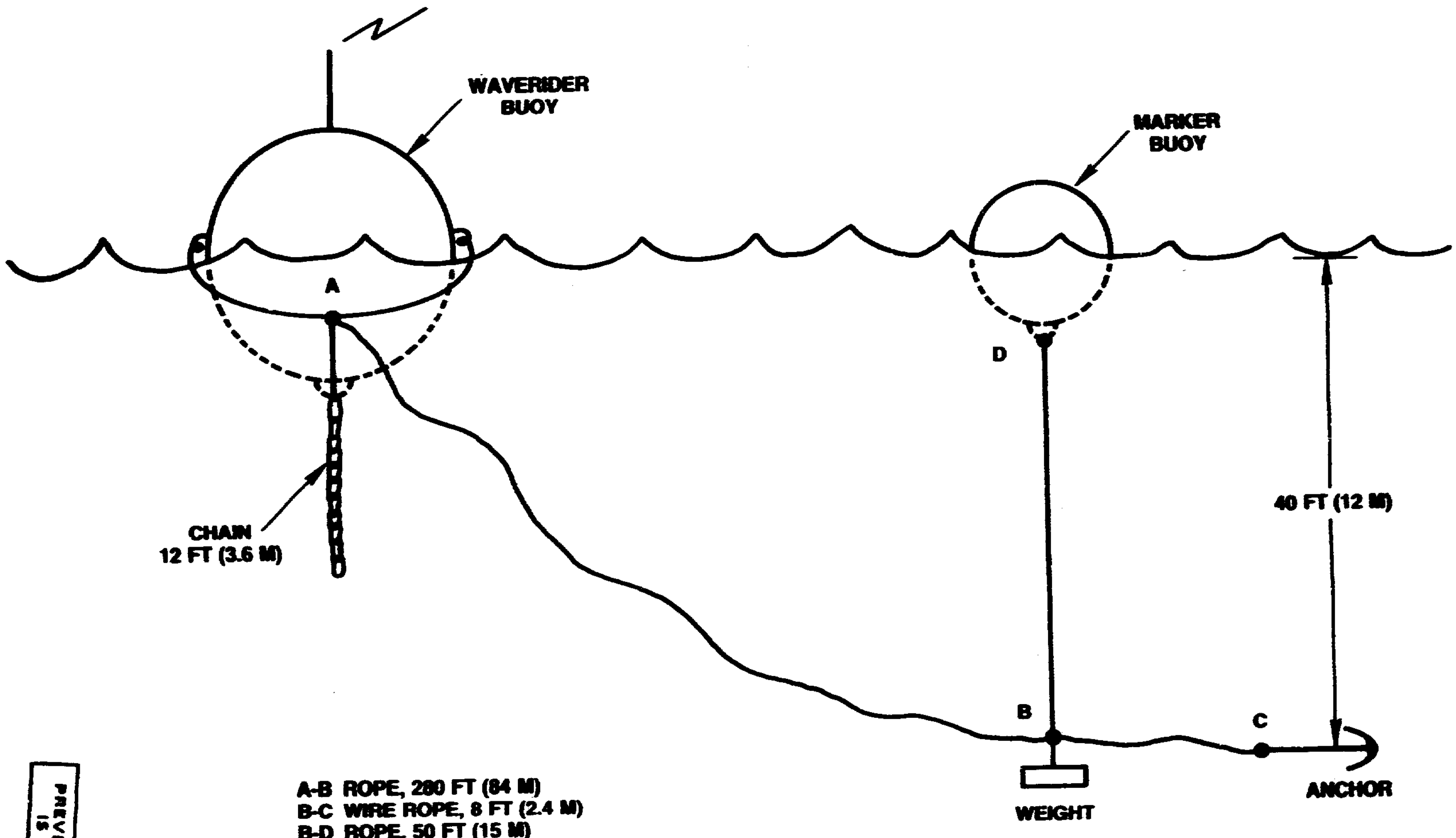


Figure 10 - Sketch of the Wave Buoy Mooring Configuration

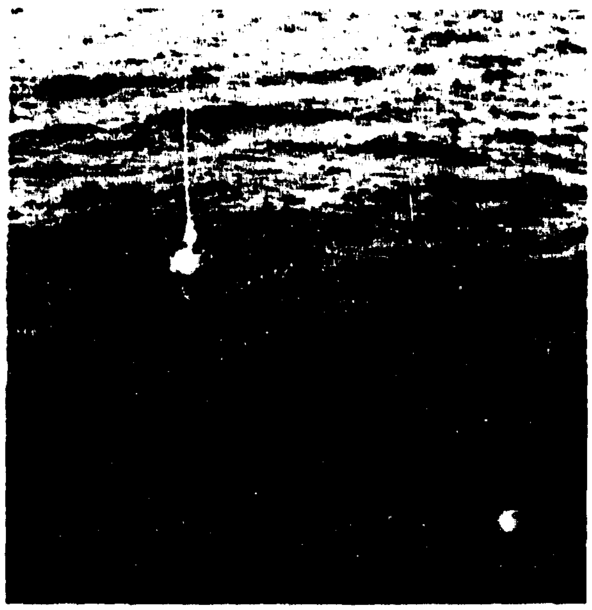
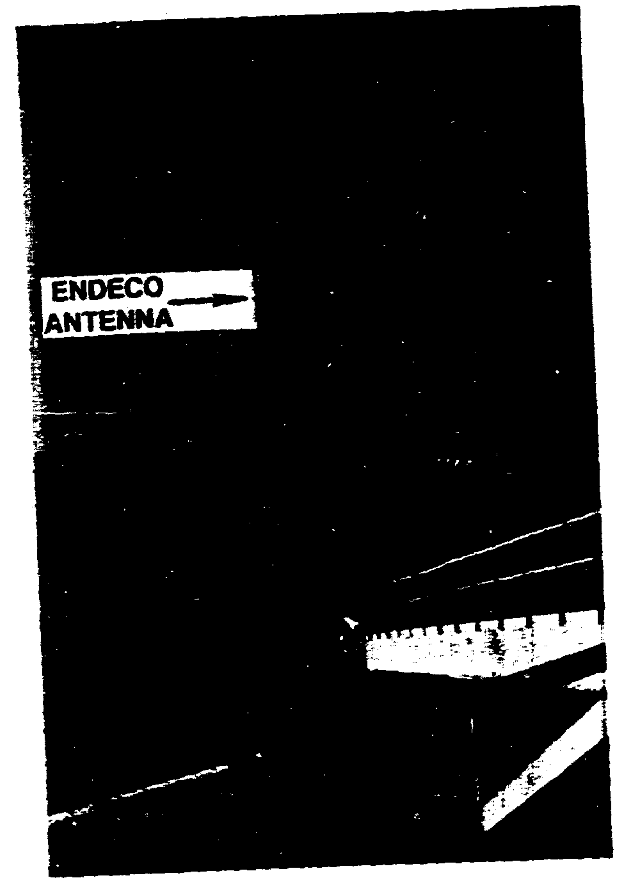

WAVERIDER BUOY

Figure 11 - Photograph of the Wave Buoy as Deployed in the Trial OPS Area

WIND METER AND WAVERIDER BUOY (SURF) ANTENNA



ENDECO BUOY (SHIP) ANTENNA

Figure 12 - Photographs of the Wind Meter and Wave Buoy Receiving Antenna

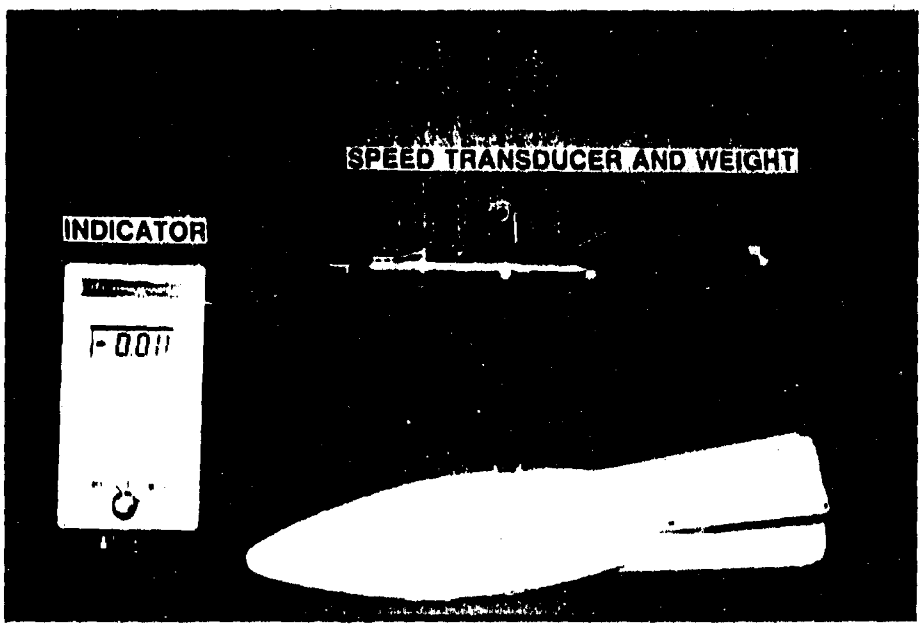
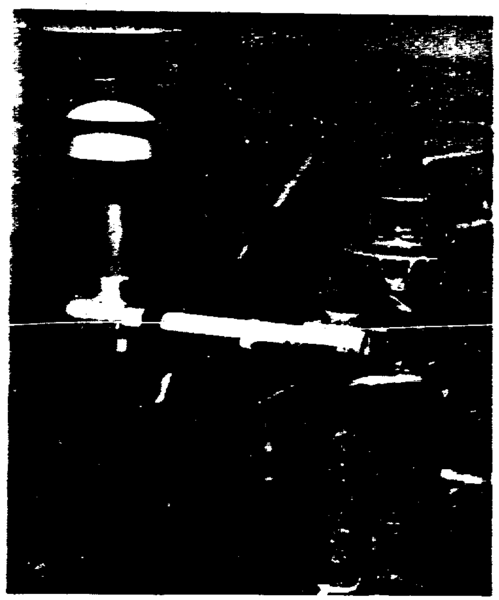
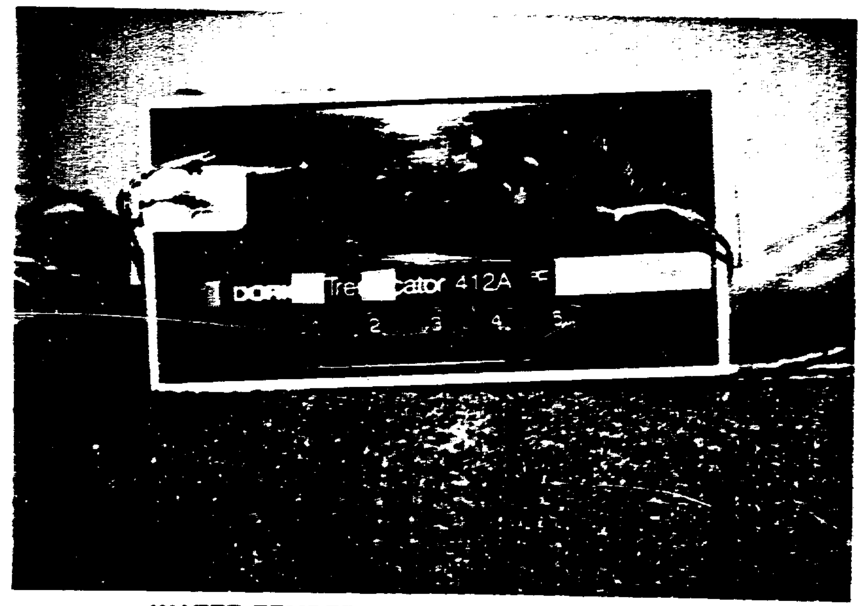


Figure 13 - Photograph of the Current Meter

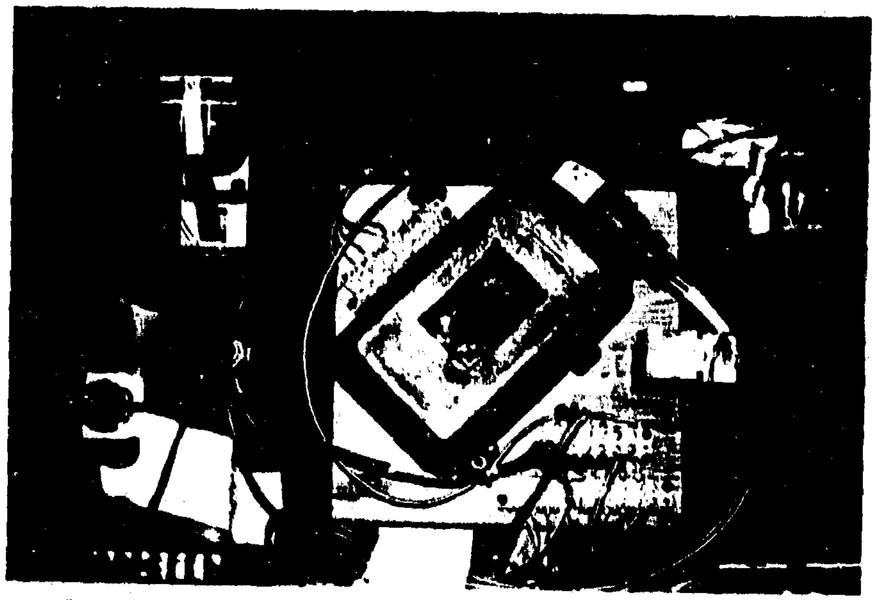


RAIN GAGE AND AIR TEMPERATURE PROBE

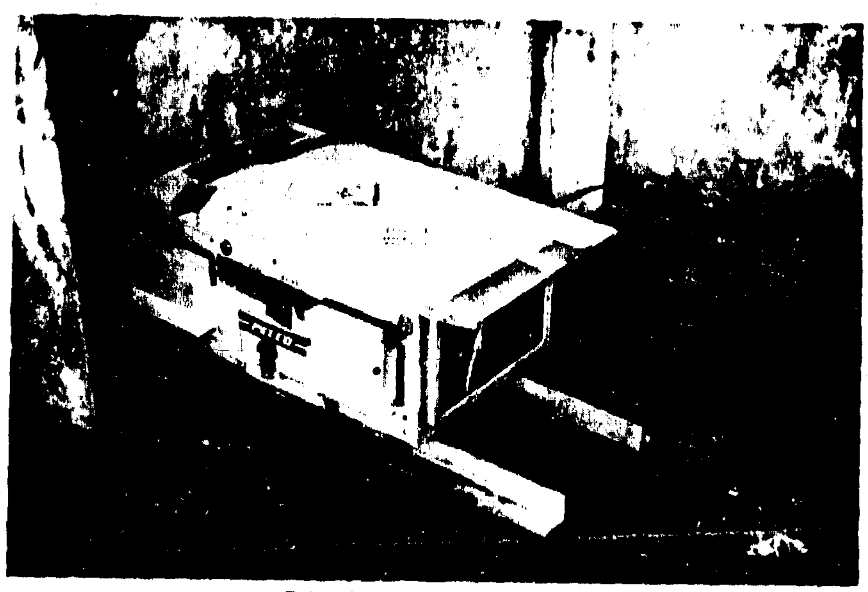


WATER TEMPERATURE PROBE (COILED UP) AND TEMPERATURE INDICATOR

Figure 14 - Photographs of the Rain Gage and Temperature Probes



COVER REMOVED TO SHOW GYRO AND ACCELEROMETER



PACKAGE IN POSITION

Figure 15 - Photographs of the Motion Measurement Package

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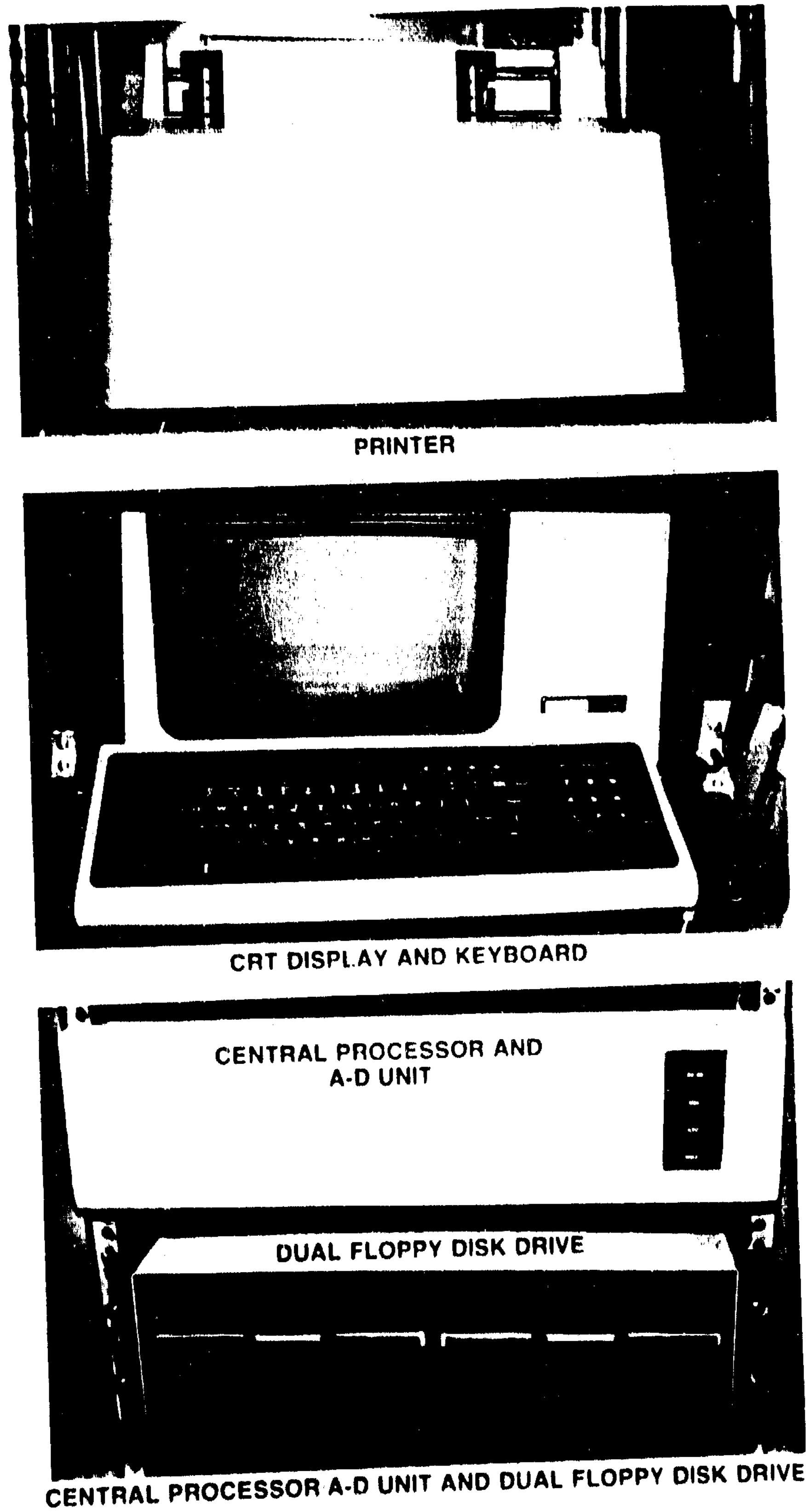

Figure 16 - Photographs of the PDP 1123 Computer System as Installed in PORDACC

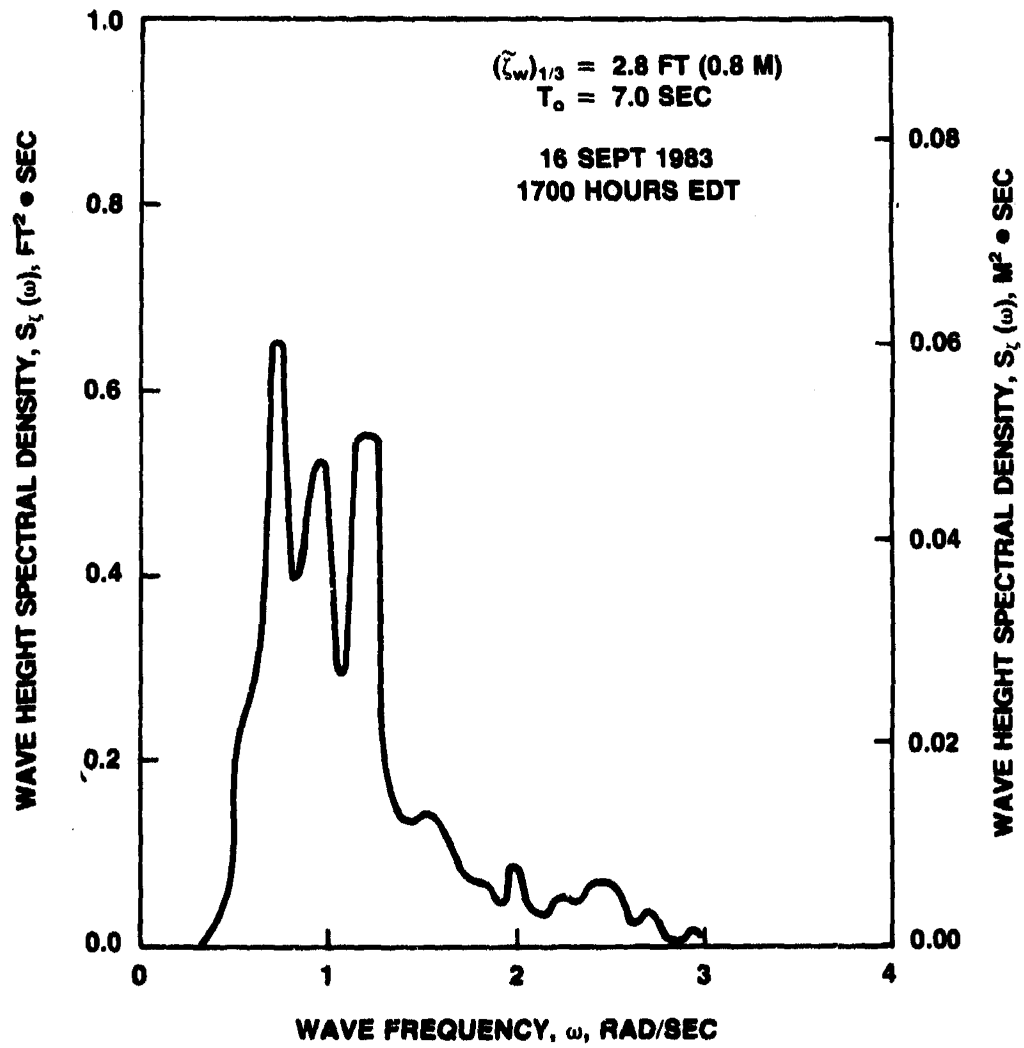

Figure 17 - Wave Spectrum Representing the Maximum Wave Conditions Encountered during the First Day of the Trial (16 September 1983)

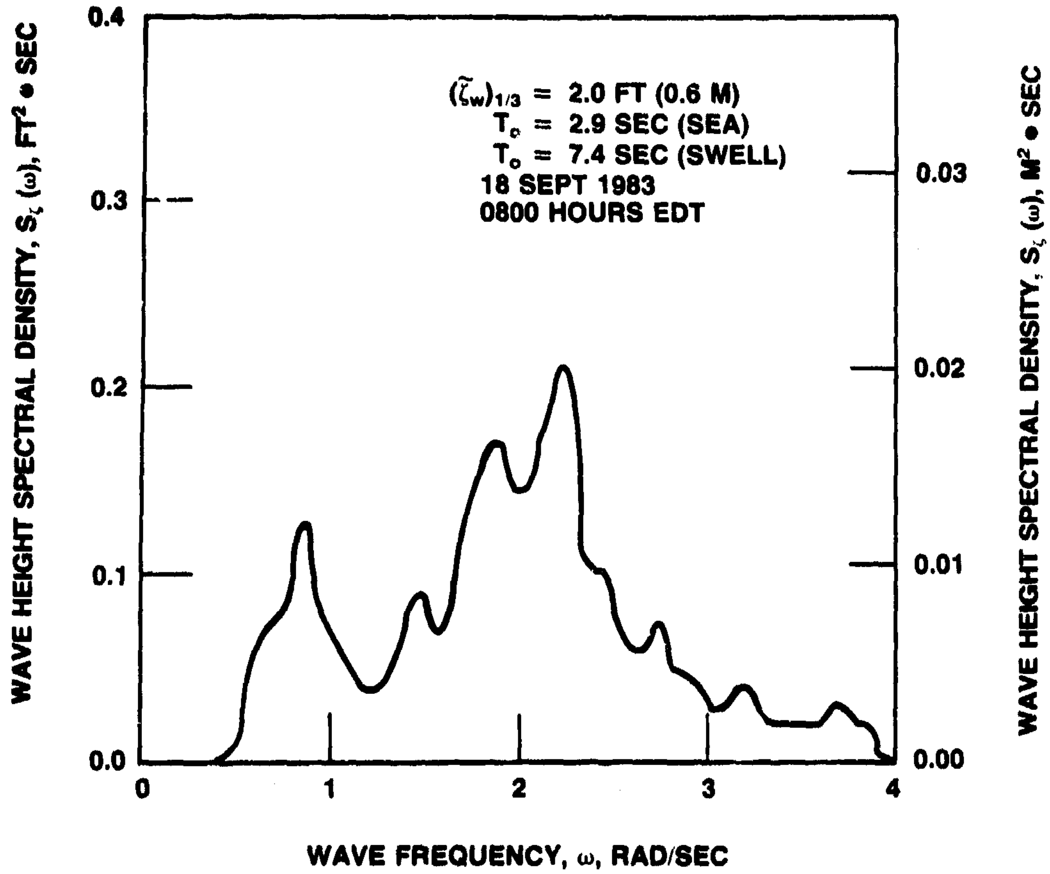

Figure 19 - Wave Spectrum Representing the Maximum Wave Conditions Encountered during the Third Day of the Trial (18 September 1983)

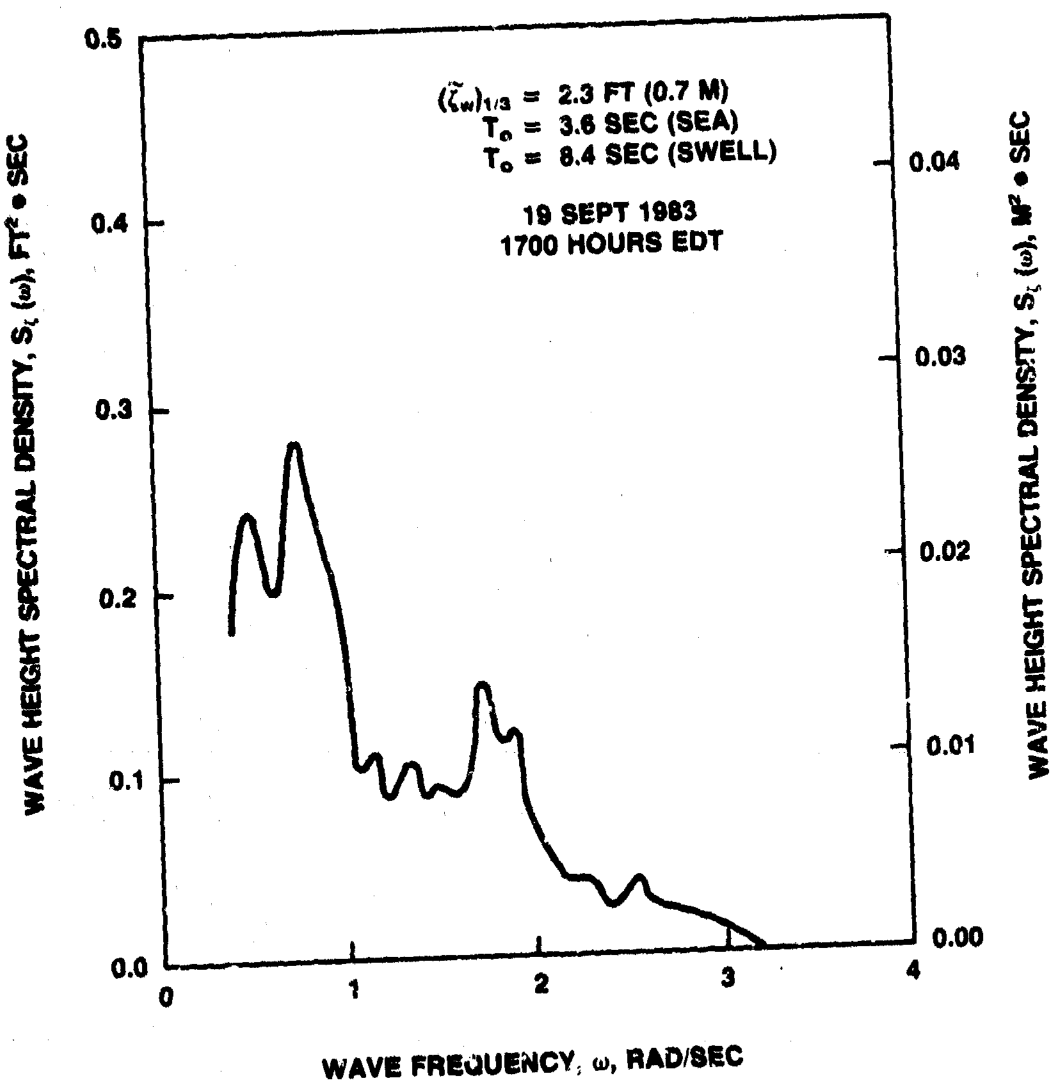

Figure 20 - Wave Spectrum Representing the Maximum Wave Conditions Encountered during the Fourth Day of the Trial (19 September 1983)

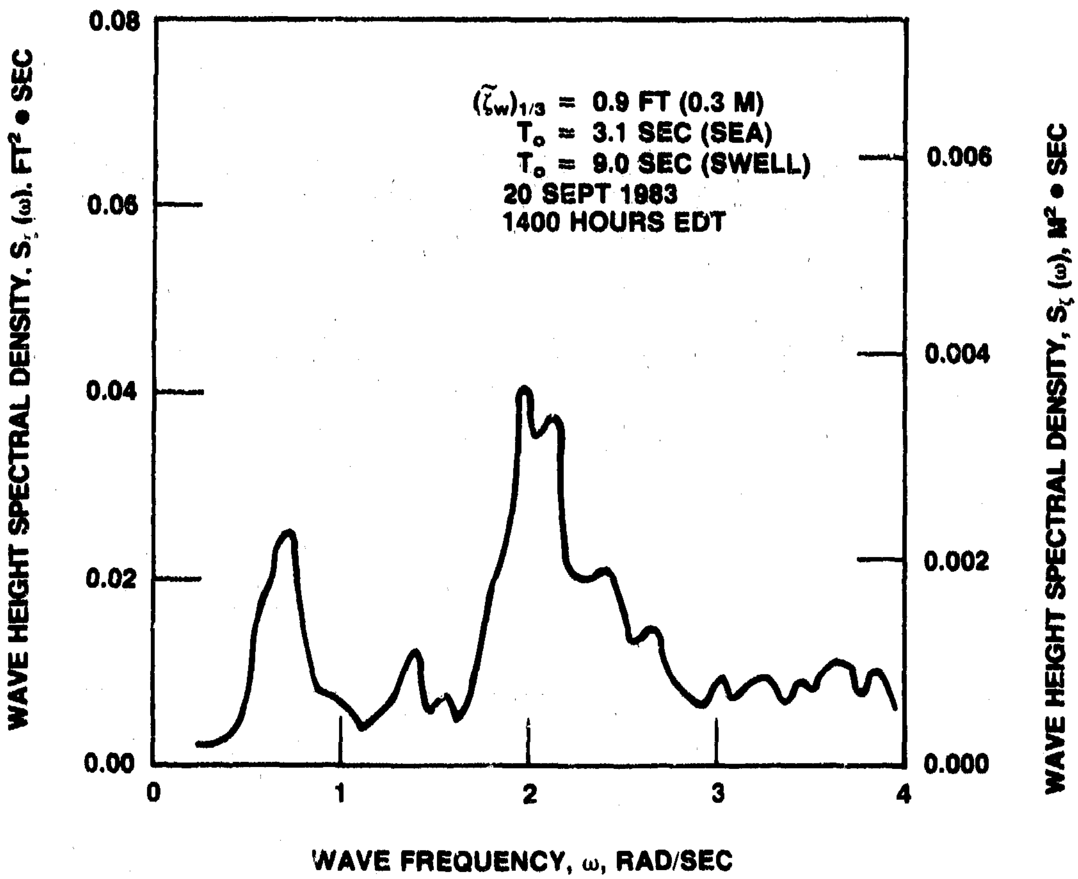

Figure 21 - Wave Spectrum Representing the Maximum Wave Conditions Encountered during the Fifth Day of the Trial (20 September 1983)

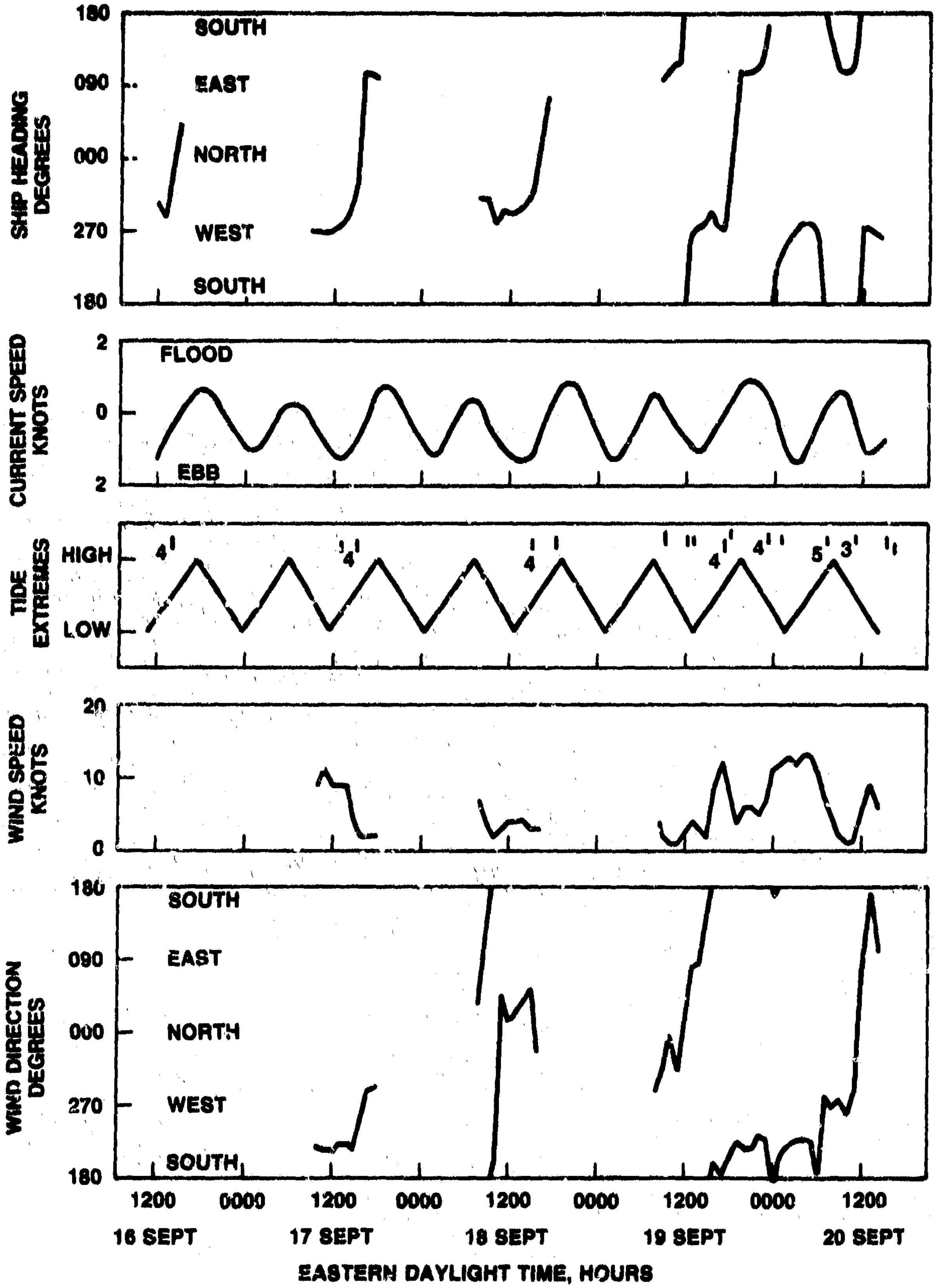

Figure 22 - Ship Heading Variations and Influencing Environmental Conditions versus Date and Time Obtained during the Trial

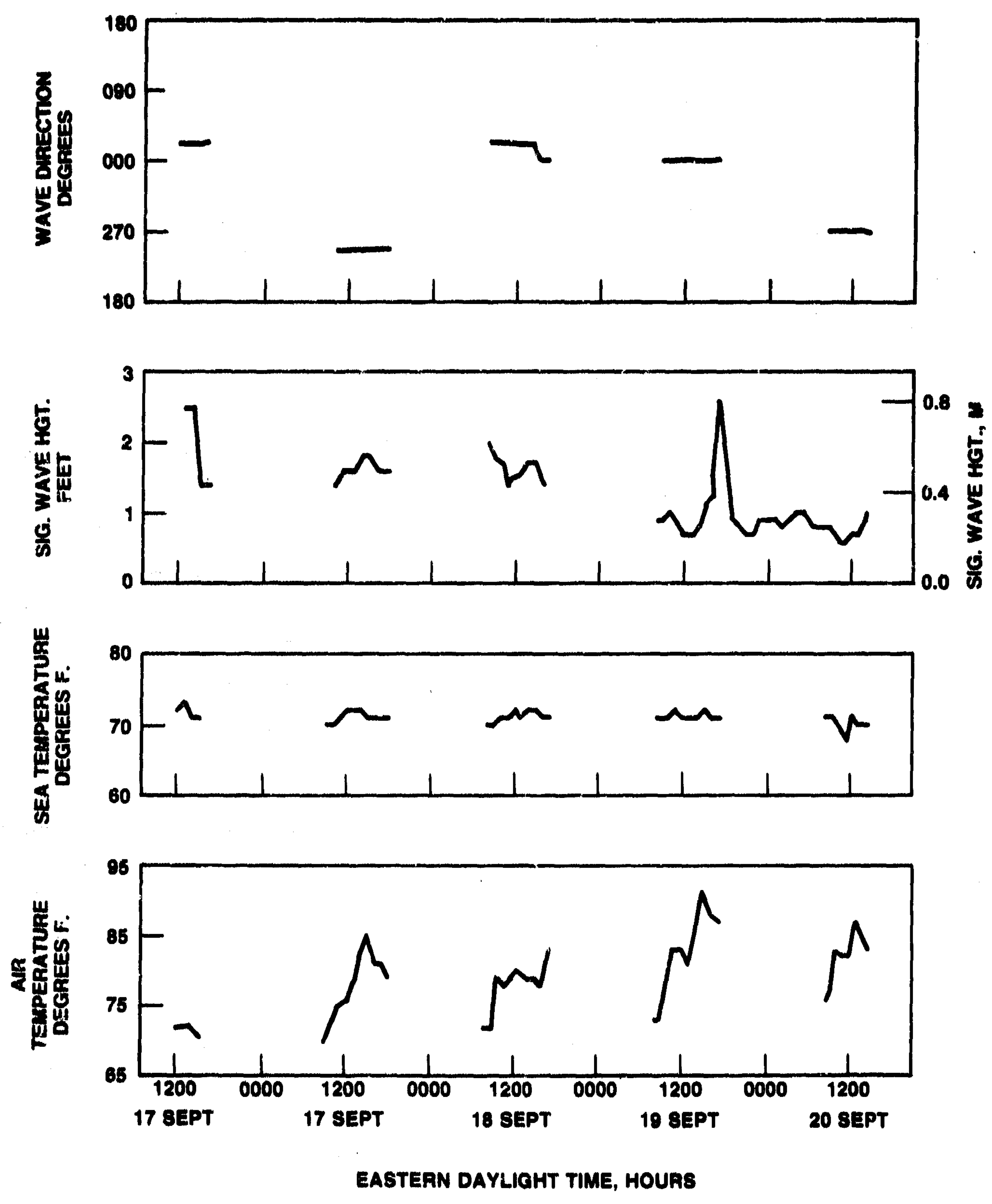

Figure 23 - Wave and Temperature Variations versus Date and Time Obtained during the Trial

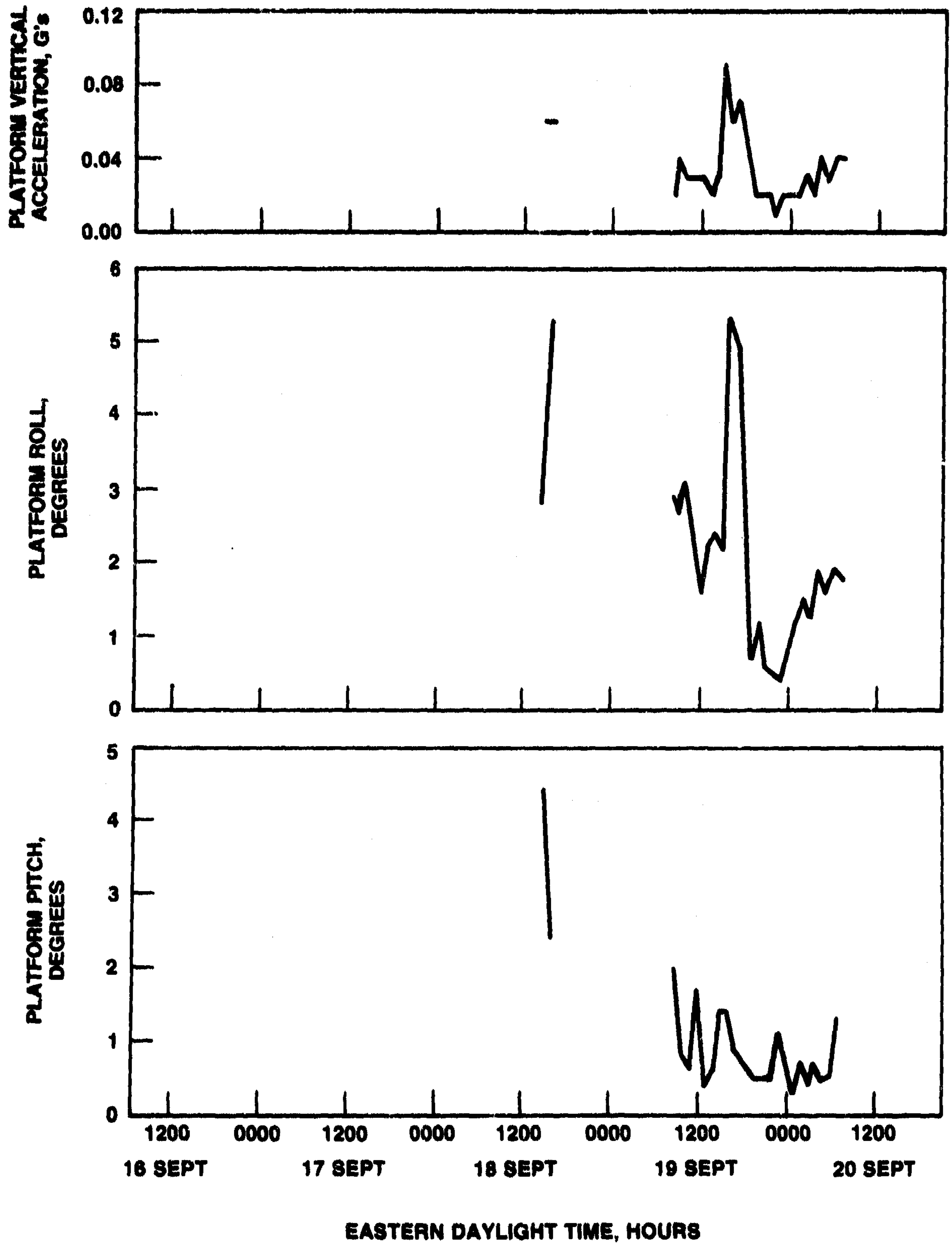

Figure 24 - Platform Motion Range Variations versus Date and Time Obtained during the Trial

TABLE 2 - SUMMARY OF MEASUREMENTS DURING THE TRIAL

Measurement	Location	Transducer
Wave height	Near the ship	Waverider buoy
Wind speed	Forward, ship's upper deck	Anemometer
Wind direction	Forward, ship's upper deck	Anemometer
Current speed	Side of CHATTANOOGA	Current meter
Water temperature	Side of CHATTANOOGA	Temperature probe
Air temperature	Top of PORDACC	Temperature probe
Precipitation	Top of PORDACC	Rain gage
Barometric pressure	Inside PORDACC	Barometer
Ship heading	CHATTANOOGA pilot house	Gyrocompass
Ship pitch	Port side, main deck	Gyroscope
Ship roll	Port side, main deck	Gyroscope
Ship vertical acceleration	Port side, main deck	Vertical accelerometer
Platform pitch	Causeway platform	Gyroscope
Platform roll	Causeway platform	Gyroscope
Platform vertical acceleration	Causeway platform	Vertical accelerometer
Horizontal ramp acceleration	Top of ramp	Horizontal accelerometer
LCU pitch	Inside PORDACC	Gyroscope
LCU roll	Inside PORDACC	Gyroscope

TABLE 1 - PARTICULARS OF THE SS ATLANTIC BEAR, LCU, WARPING TUG, AND A TYPICAL CAUSEWAY SECTION

Particular	SS ATLANTIC BEAR	LCU	Warping Tug	Causeway Section
Class	GREAT LAND	LCU 1610	LWT (Home Port Type)	C, B
LOA, ft, m	790 (241)	134.9 (41.1)	92.9 (28.3)	90.0 (27.4)
B, ft, m	105 (32)	29.0 (8.8)	23.0 (7.0)	21.0 (6.4)
T, ft, m	28 (9)	6.1 (1.9)	6.5 (2.0)	1.65 (0.5)
Δ, LTSW, tonnes	16,100 (16,357)	375.0 (381.0)	120.0 (122.0)	80.0 (81.4)

TABLE 3 - SUMMARY OF ENVIRONMENTAL CONDITIONS DURING THE TRIAL

Date	Time hrs, EDT	Temperature deg F.		Wind Speed and Direction		Significant Wave Height ft (m)	Wind Direction	Current E-Ebb, F-Flood		Visibility nm (km)	Barometer Reading
		Water	Air	knots	deg			Speed Knots	Direction		
16 Sept	1200	72	72	—	—	—		—	—	Very Clear	30.44
	1300	73	72	—	—	2.5 (0.8)	NNE	—	—	15 (27.0)	30.44
	1400	71	72	—	—	2.5 (0.8)		—	—		30.42
	1500	71	71	—	—	1.4 (0.4)		—	—		30.40
	1700	—	—	—	—	1.4 (0.4)		—	—		—
17 Sept	0900	70	70	—	—	—	WSW	—	—	Clear	30.38
	1000	70	73	9	221	1.4 (0.4)		—	—	10 (18.0)	30.38
	1100	71	75	11	217	1.6 (0.5)		—	—		30.36
	1200	72	76	9	212	1.6 (0.5)		—	—		30.36
	1300	72	78	9	224	1.6 (0.5)		—	—		30.34
	1400	72	82	9	220	1.8 (0.5)		—	—		30.30
	1500	71	85	4	211	1.8 (0.5)		—	—		30.27
	1600	71	81	2	256	1.6 (0.5)		—	—		30.26
	1700	71	81	2	293	1.6 (0.5)		0	E/F		30.26
	1800	71	79	2	297	1.6 (0.5)		0	E/F		30.26
18 Sept	0800	70	72	7	034	2.0 (0.6)	NNE	0.4	E	Clear	30.37
	0900	70	72	4	120	1.8 (0.5)		0.4	E	10 (18.0)	30.40
	1000	71	79	2	200	1.7 (0.5)		—	—		30.41
	1100	71	78	3	044	1.4 (0.4)		—	—		30.42
	1200	72	79	4	018	1.5 (0.5)		—	—		30.44
	1230	71	80	4	020	1.5 (0.5)		—	—		30.43
	1400	72	79	4	034	1.7 (0.5)		—	—		30.43
	1500	72	79	3	054	1.7 (0.5)	N	—	—		30.43
	1600	71	78	3	339	1.4 (0.4)		0.8	E		30.41
	1700	71	83	—	—	—		0	E/F		30.42
19 Sept	0830	71	73	4	288	0.9 (0.3)	N	0.4	F	Light Haze	30.49
	0900	71	73	2	316	0.9 (0.3)		0.4	F	4 (7.2)	30.46
	1000	71	79	1	355	1.0 (0.3)		0	E/F		30.47

TABLE 3 (Continued)

Date	Time hrs, EDT	Temperature deg F.		Wind Speed and Direction		Significant Wave Height ft (m)	Wind Direction	Current E-Ebb, F-Flood		Visibility nm (km)	Barometer Reading
		Water	Air	knots	deg			Speed Knots	Direction		
	1100	72	83	1	313	0.8 (0.2)		0.4	E		30.48
	1200	71	83	2	023	0.7 (0.2)		0.2	E	Fair	30.48
	1300	71	81	4	080	0.7 (0.2)		0.7	E	6 (10.8)	30.46
	1400	71	86	3	085	0.8 (0.2)		1.0	E		30.45
	1500	72	91	2	150	1.1 (0.3)		0.7	E		30.43
	1600	71	88	9	200	1.2 (0.4)		0.3	E		30.41
	1700	71	87	12	190	2.6 (0.8)		—	—		30.40
	1900	—	—	4	223	0.9 (0.3)		—	—		—
	2000	—	—	6	209	0.8 (0.2)	Dark	—	—	Dark	—
	2100	—	—	6	213	0.7 (0.2)		—	—		—
	2200	—	—	5	235	0.7 (0.2)		—	—		—
	2300	—	—	7	232	0.9 (0.3)		—	—		—
	2400	—	—	11	171	0.9 (0.3)		—	—		—
20 Sept	0100	—	—	13	201	0.9 (0.3)		—	—		—
	0200	—	—	12	217	0.8 (0.2)		—	—		—
	0300	—	—	13	227	0.9 (0.3)		—	—		—
	0400	—	—	13	229	1.0 (0.3)		—	—		—
	0500	—	—	11	227	1.0 (0.3)		—	—		—
	0600	—	—	7	190	0.8 (0.2)		—	—		—
	0700	—	—	4	280	0.8 (0.2)		—	—		—
	0830	—	—	2	271	0.8 (0.2)	W	0.4	F	Light Haze	30.40
	0900	—	—	2	276	0.7 (0.2)		0.5	F	5 (9.0)	30.45
	1000	—	—	1	262	0.6 (0.2)		0.3	F		30.47
	1100	—	—	1	286	0.6 (0.2)		—	—		30.47
	1200	—	—	5	080	0.7 (0.2)		—	—		30.46
	1300	—	—	9	174	0.7 (0.2)		1.0	E		30.42
	1400	—	—	6	100	1.0 (0.3)		0.8	E		30.42

TABLE 4 - SUMMARY OF MOTION SIGNIFICANT AMPLITUDES

Date	Time hrs, EDT	Ship Pitch deg	Ship Roll deg	Ship Vertical Acceleration g's	Ship* Heading deg	Platform Pitch deg	Platform Roll deg	Platform Vertical Acceleration g's	Horizontal Ramp Acceleration g's	LCU Pitch deg	LCU Roll deg
17 Sept	1500	0.2	0.5	0.012	328	—	—	—	—	0.2	0.8
	1600	0.1	0.4	0.007	117	—	—	—	—	1.7	1.4
	1700	0.1	0.4	0.006	115	—	—	—	—	1.4	1.2
	1800	0.1	0.3	0.005	107	—	—	—	—	1.3	1.0
18 Sept	0800	1.2	2.4	0.005	311	—	—	—	—	2.4	1.2
	0900	0.1	0.2	0.006	310	—	—	—	—	0.3	0.7
	1000	0.1	0.8	0.036	282	—	—	—	—	0.3	0.4
	1100	0.1	0.3	0.003	298	—	—	—	—	0.2	0.4
	1200	0.1	0.2	0.004	293	—	—	—	—	0.2	0.5
	1230	0.1	0.3	0.003	295	—	—	—	—	0.3	0.4
	1400	0.1	0.3	0.004	305	—	—	—	—	0.2	0.4
	1500	0.1	0.6	0.009	321	0.9	0.7	0.013	—	0.2	0.6
	1600	0.2	0.8	0.003	029	0.7	2.7	0.018	—	0.2	0.6
19 Sept	0830	—	—	0.003	100	0.1	0.2	0.006	—	1.4	0.6
	0900	0.2	0.5	0.003	102	0.2	0.5	0.007	—	0.7	0.5
	1000	0.2	0.3	0.003	126	0.3	0.6	0.007	—	0.5	0.7
	1100	0.1	0.3	0.003	131	0.2	0.4	0.006	—	0.5	0.5
	1200	0.1	0.1	0.002	241	0.2	0.5	0.007	—	0.4	0.4
	1300	0.1	0.1	0.001	271	0.1	0.6	0.006	—	0.3	0.2
	1400	0.1	0.1	0.002	278	0.2	0.7	0.007	—	0.2	0.4
	1500	0.1	0.3	0.003	291	0.4	0.7	0.010	—	0.2	0.4

*Mean values.

TABLE 4 (Continued)

Date	Time hrs, EDT	Ship Pitch deg	Ship Roll deg	Ship Vertical Acceleration g'a	Ship* Heading deg	Platform Pitch deg	Platform Roll deg	Platform Vertical Acceleration g's	Horizontal Ramp Acceleration g's	LCU Pitch deg	LCU Roll deg
	1600	0.1	0.2	0.003	280	0.4	1.4	0.015	--	0.3	0.3
	1700	0.1	0.6	0.003	275	0.2	1.6	0.020	--	0.5	0.4
	1900	0.1	0.2	--	118	0.2	0.2	0.006	0.005	0.7	0.5
	2000	0.1	0.2	--	117	0.2	0.5	0.006	0.004	0.6	0.5
	2100	0.1	0.2	--	122	0.2	0.2	0.005	0.004	0.5	0.6
	2200	0.1	0.3	--	128	0.1	0.2	0.005	0.004	0.4	0.6
	2300	0.1	0.3	--	168	0.3	0.1	0.007	0.007	0.2	0.7
	2400	0.1	0.1	--	227	0.2	0.3	0.006	0.002	0.3	0.3
20 Sept	0100	0.1	0.1	--	250	0.1	0.4	0.005	0.002	0.2	0.2
	0200	0.1	0.1	--	265	0.1	0.5	0.009	0.004	0.2	0.2
	0300	0.1	0.1	--	277	0.1	0.5	0.007	0.004	0.1	0.2
	0400	0.1	0.1	--	281	0.2	0.6	0.010	0.006	0.2	0.2
	0500	0.1	0.1	--	282	0.2	0.5	0.010	0.005	0.3	0.3
	0600	0.1	0.1	--	259	0.2	0.5	0.010	0.005	0.4	0.2
	0700	0.1	0.4	--	168	0.5	0.5	0.013	0.009	0.3	0.9
	0800	0.1	0.2	--	125	--	--	--	--	0.5	0.4
	0900	0.1	0.3	--	119	--	--	--	--	0.5	0.5
	1000	0.1	0.2	--	118	--	--	--	--	0.4	0.5
	1100	0.1	0.4	--	154	--	--	--	--	0.4	0.7
	1200	0.1	0.1	--	276	--	--	--	--	0.2	0.2
	1300	0.1	0.1	--	269	--	--	--	--	0.2	0.2

*Mean values.

TABLE 5 - SUMMARY OF MOTION RANGE VALUES

Date	Time hrs, EDT	Ship Pitch deg	Ship Roll deg	Ship Vertical Acceleration g's	Ship Heading deg	Platform Pitch deg	Platform Roll deg	Platform Vertical Acceleration g's	Horizontal Ramp Acceleration g's	LCU Pitch deg	LCU Roll deg
17 Sept	1500	0.5	1.9	0.038	025	--	--	--	--	0.8	2.4
	1600	0.4	1.3	0.021	015	--	--	--	--	5.6	4.8
	1700	0.4	1.5	0.021	011	--	--	--	--	5.0	3.5
	1800	0.4	1.0	0.068	014	--	--	--	--	4.2	3.5
18 Sept	0800	1.7	3.6	0.017	416	--	--	--	--	5.1	4.7
	0900	0.3	0.7	0.023	019	--	--	--	--	0.8	2.4
	1000	0.4	1.4	--	009	--	--	--	--	1.2	1.4
	1100	0.4	0.9	0.010	027	--	--	--	--	0.8	1.1
	1200	0.4	0.6	0.060	012	--	--	--	--	0.7	1.5
	1230	0.3	0.7	0.012	004	--	--	--	--	0.8	1.5
	1400	0.4	0.9	0.015	007	--	--	--	--	0.7	1.5
	1500	0.4	1.6	0.027	023	4.4	2.8	0.059	--	0.7	2.1
	1600	0.4	1.4	0.010	005	2.4	5.3	0.057	--	0.6	2.2
19 Sept	0830	--	--	0.009	039	2.0	2.9	0.023	--	3.7	3.4
	0900	0.5	1.1	0.010	007	2.0	2.7	0.037	--	2.9	2.0
	1000	0.5	1.0	0.011	016	0.8	3.1	0.033	--	1.8	2.4
	1100	0.4	0.8	0.013	015	0.6	2.4	0.035	--	1.6	2.0
	1200	0.2	0.6	0.010	057	1.7	1.6	0.027	--	1.5	1.5
	1300	0.2	0.8	0.006	004	0.4	2.2	0.024	--	0.8	0.7
	1400	0.2	0.4	0.007	005	0.6	2.4	0.030	--	0.7	2.1
	1500	0.3	0.8	0.009	014	1.4	2.2	0.088	--	0.9	1.8

TABLE 5 (Continued)

Date	Time hrs, EDT	Ship Pitch deg	Ship Roll deg	Ship Vertical Acceleration g's	Ship Heading deg	Platform Pitch deg	Platform Roll deg	Platform Vertical Acceleration g's	Horizontal Ramp Acceleration g's	LCU Pitch deg	LCU Roll deg
	1600	0.5	0.6	0.009	044	1.4	5.3	0.063	--	1.2	1.1
	1700	0.2	1.0	0.010	017	0.9	4.9	0.070	--	1.8	1.5
	1900	0.2	0.5	--	005	0.6	0.7	0.021	0.013	2.5	1.4
	2000	0.2	0.6	--	005	0.5	1.2	0.017	0.013	2.1	1.4
	2100	0.2	0.7	--	003	0.5	0.6	0.017	0.014	1.8	1.7
	2200	0.2	0.6	--	003	0.5	0.5	0.014	0.015	1.3	1.5
	2300	0.3	0.8	--	010	1.1	0.4	0.020	0.020	0.5	2.0
	2400	0.2	0.3	--	005	0.7	0.8	0.020	0.007	0.9	0.8
20 Sept	0100	0.2	0.2	--	004	0.3	1.2	0.021	0.007	0.6	0.5
	0200	0.2	0.2	--	002	0.7	1.5	0.030	0.011	0.6	0.6
	0300	0.2	0.3	--	003	0.4	1.3	0.022	0.013	0.4	0.5
	0400	0.2	0.3	--	003	0.7	1.9	0.036	0.018	0.6	0.8
	0500	0.2	0.3	--	004	0.6	1.6	0.030	0.014	0.7	0.7
	0600	0.2	0.3	--	004	0.5	1.9	0.042	0.015	1.2	0.7
	0700	0.3	1.0	--	015	1.3	1.8	0.041	0.030	0.9	2.7
	0800	0.3	0.6	--	007	--	--	--	--	1.9	2.0
	0900	0.4	1.1	--	007	--	--	--	--	1.6	2.0
	1000	0.3	0.7	--	005	--	--	--	--	1.4	1.6
	1100	0.2	1.1	--	055	--	--	--	--	1.6	2.7
	1200	0.2	0.5	--	021	--	--	--	--	0.7	0.7
	1300	0.2	0.4	--	007	--	--	--	--	0.6	0.7